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CONTENTS

The clonal propagation of red clover - *H. L. Barrales and R. A. Ludwig* 455

Chemical composition and digestibility of forage crops grown in Central Saskatchewan, with observations on Kochia species - - *J. M. Bell, G. H. Bowman and R. T. Coupland* 463

Uptake by plants of labelled phosphates from neutron-irradiated calcium phosphates:

I. Uptake by seedlings from solution cultures - - - 474

II. Uptake by seedlings from soil-sand cultures - - - 480
J. G. A. Fiskell, W. A. DeLong and W. F. Oliver

Hoary cresses in Canada with particular reference to their distribution and control in Alberta - *W. G. Corns and C. Frankton* 484

Supplementation of alfalfa and marsh hays with linseed, rapeseed and mustardseed oil meals in gestation rations for ewes - - - - *J. M. Bell and J. A. Weir* 496

The discovery of nematodes belonging to the genus *Heterodera* in British Columbia and their host relationships
R. J. Hastings and J. E. Bosher 507

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SCIENTIFIC AGRICULTURE

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THE CLONAL PROPAGATION OF RED CLOVER[1]

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[Received for publication January 10, 1952]

Red clover is a cross pollinated crop. As a result considerable variation occurs between the plants, and progeny grown from seed may be expected to differ greatly from the parent plant. In consequence, studies on red clover are complicated since observations, on plants grown from seed, must be made on single plants rather than on replicated groups of plants. This difficulty can be overcome through the use of clonally propagated individual plant lines.

Scholz and Smidrkal (5) studied methods of vegetatively propagating a number of herbage plants including red clover. They obtained poor rooting in untreated stem cuttings of red clover but reported considerable improvement through the use of rooting hormones. Nowosad (4) also concluded that the use of rooting hormone was advantageous.

Hanson (2) found that the stage of growth of the parent plant affected the ease of vegetation propagation. Cuttings obtained from actively growing stems rooted much more easily than did those obtained from plants in the flowering stage. He also found that the best rooting was obtained between temperatures of 75° and 85° F. While the rate of rooting increased with increasing temperature, the percentage of rooting was greatly reduced at 95° F.

The work reported in this paper represents a further study of the vegetative propagation of red clover, undertaken with a view to developing a simple, effective method for use in experimental work on this crop.

VEGETATIVE PROPAGATION OF RED CLOVER BY CROWN CUTTINGS

It was found, in studies on the photoperiodism of red clover, that reducing the daylength below the critical level for flowering resulted in a gradual decrease in stem elongation and increase in crown bud formation. This effect was very pronounced in plants exposed to alternate periods of 8 hours' light and 16 hours' darkness under the temperature conditions (approximately 65° to 75° F.) prevailing during the course of the experiments. Three 3-month old seedling plants conditioned in this way are shown in Figure 1.

Cuttings taken vertically from these plants in such a way as to include a single bud and a portion of the crown were found to root readily in moist

[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Quebec. Journal Series No. 295. Part of a thesis presented by H. L. Barrales in partial fulfilment of the requirements for the degree of Master of Science.

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FIGURE 1. Growth habit of red clover plants grown under short-day conditions.

sand when kept under reasonably cool temperature conditions and in diffuse light. Removal of all leaves except the newly expanding ones reduced transpiration and seemed to favour rooting.

Individual plants varied in the ease with which they could be rooted by this method. Under proper conditions of temperature and light, however, 100 per cent rooting has been obtained from most plants.

The chief limitation of this method lies in the fact that the plants must be kept for at least two months under conditions of 8-hour day-length prior to propagating in order to induce a suitable type of growth. Since this day-length does not prevail naturally in the latitude of Montreal, even in midwinter, it is necessary to artificially darken the plants. The plants to be propagated cannot always be suitably conditioned; hence methods of propagation by stem cuttings were explored as an alternative.

VEGETATIVE PROPAGATION OF RED CLOVER BY STEM CUTTINGS

Seventeen clonal lines of Dollard red clover were used in an experiment designed to test the effect of previous day-length treatment, position of cutting and hormone treatment on the rooting of stem cuttings. The parent plants were propagated by means of crown cuttings and grown for approximately two months under 8-hour day-length conditions prior to initiating the experiment. Half of the plants from each clonal line were then kept under short days (8-hour day-length) and half under long days (natural day-length of 15 to 16 hours) for a further period of two months prior to the taking of cuttings so that the effect of previous photoperiod on rooting could be compared. Cuttings from the basal, medium and upper portions of the stems were used in each case. All cuttings were taken in such a way as to include two nodes and varied in length from $1\frac{1}{2}$ to 2 inches, the shorter ones coming from short-day plants where internodal elongation had been reduced. At least one leaf was left attached to the upper node in each case. The cuttings were planted in moist sand for rooting, one node being immersed and the other just above the sand. Four replicates were prepared, one short-day and one long-day plant from each clonal line being used in each replicate. Two stems were taken from each plant. The three cuttings from one of these stems were planted directly while the other three were treated with rooting hormone prior to planting. These were treated dry by dusting with "Stim Root Hormone Powder", a commercial

preparation containing indol butyric and alpha naphthyl acetic acids. Cool conditions (60° to 70° F.) were maintained throughout the rooting period and partial shading provided by covering with a single layer of cheesecloth. The rooting medium was kept moist but not saturated throughout the experiment. Notes were taken on the percentage of rooting after 25 days.

The experiment was analysed as a randomized block. The figures for replicates were pooled and the total for each treatment was expressed as the percentage of rooted to planted cuttings. In the analysis of variance these percentages were transformed into angular units. In the breakdown of degrees of freedom, replicates were omitted. The error variance contains as a bulk all the interactions involving clonal lines as well as all second order interactions. The data presented in the form of histograms are given in percentages but when it is said that differences in percentages are significant, it is to be understood that the necessary differences was calculated and compared in transformed units.

The mean squares and the corresponding F values given in Table 1 indicate the significance of the different treatments as related to percentage of rooting.

Differences in percentage of rooted cuttings due to variation among the clonal lines were highly significant. Figure 2 is presented in order to

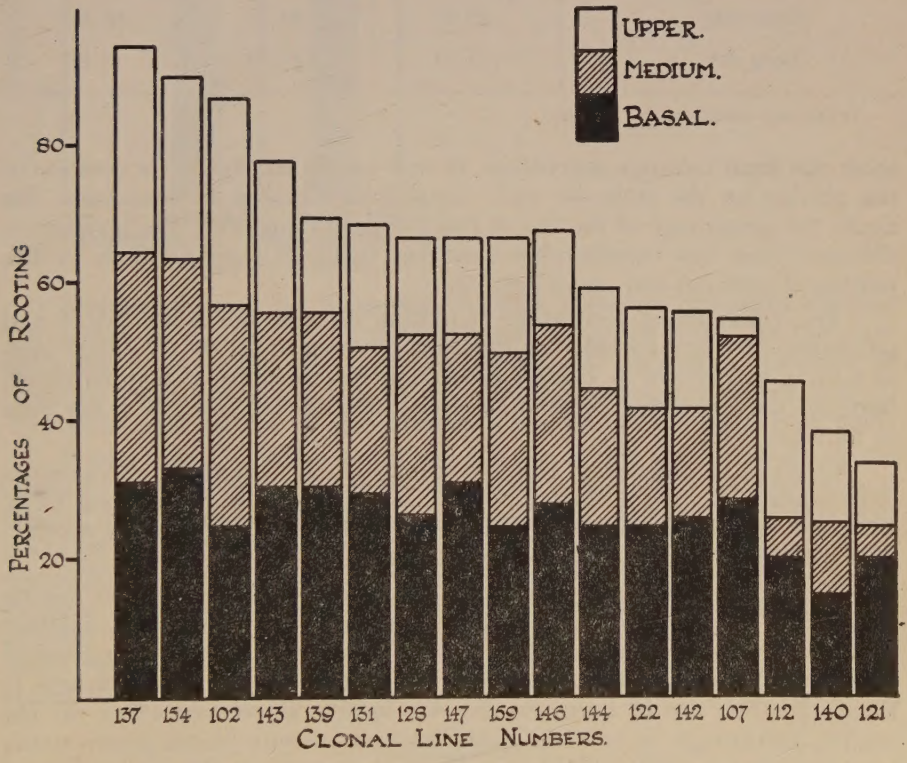

FIGURE 2. Differences in the percentages of rooting in 17 clonal lines of red clover propagated by cuttings obtained from three positions on the stem.

TABLE 1.—ANALYSIS OF VARIANCE OF THE TRANSFORMED DATA OF THE ROOTING PERCENTAGES OF STEM CUTTINGS FROM SEVENTEEN CLONAL LINES OF RED CLOVER

Source of variation	D.F.	Sum of squares	Mean squares	F
Total	203	162,313.35	—	—
Clonal lines	16	37,290.33	2,330.64	4.85**
Hormone	1	4,907.98	4,907.98	10.22**
Day-length (parent plant)	1	2,408.33	2,408.33	4.26*
Cutting (position on stem)	2	16,274.79	8,137.39	16.95**
Hormone × day-length	1	4,725.15	4,725.15	9.84*
Hormone × cuttings	2	170.81	85.40	—
Day-length × cuttings	2	11,439.88	5,719.94	11.90*
Remainder	178	85,456.08	480.09	—

* Significant at the 0.05 level.
** Significant at the 0.01 level.

TABLE 2.—MEANS FOR THE INTERACTION OF HORMONE AND DAY-LENGTH
(Data in angular units)

Day-length	Mean values in angular units		
	No hormone	Hormone	Difference
Short day	69.02	49.75	19.27**
Long day	53.23	53.04	0.19

** Difference significant at 0.01 level.

show the total rootings percentage as well as the sub-totals for position of the cutting on the stem for each clonal line. As can be seen from this figure the percentage of rooting of basal cuttings was fairly uniform in the different lines but considerable variation occurred between lines in the rooting of medium and upper cuttings.

The difference in percentage of rooting between hormone treated and untreated cuttings, considering the data obtained from the 17 clonal lines as a total, was shown in Table 1 to be highly significant. Treatment with hormone decreased the percentage of cuttings rooting from 69.9 per cent to 58.2 per cent.

Cuttings obtained from plants previously kept under short days rooted more successfully than those produced by plants grown under long days. The former averaged 67.6 per cent and the latter 60.5 per cent rooting. This difference was shown to be significant at the 5 per cent level.

The interaction of hormone × day-length (Table 1) was highly significant. The means for hormone treated and untreated cuttings obtained from parent plants grown under long and short days are given in transformed units in Table 2 and illustrated in terms of percentages in Figure 3. The use of hormone did not have a significant effect on the rooting percentage of cuttings obtained from parent plants grown under long days but caused a highly significant reduction in the percentage of rooting in cuttings taken from short-day plants.

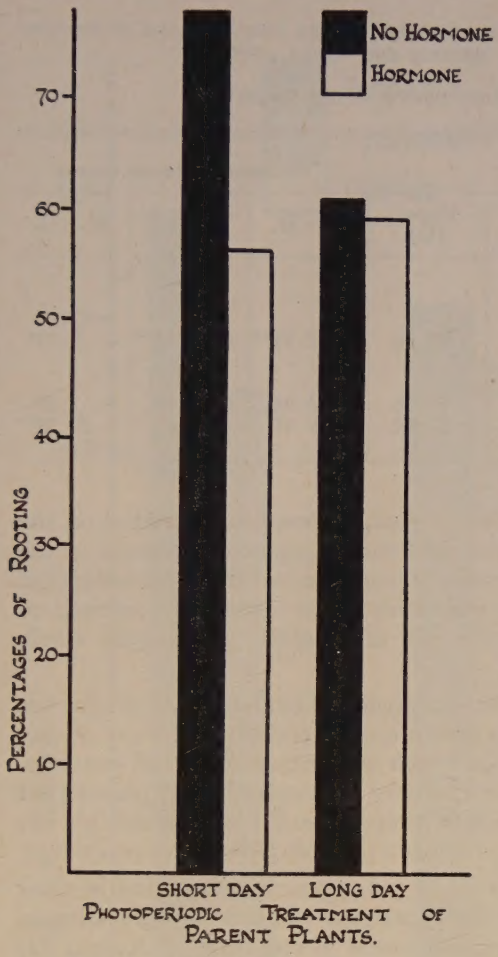

FIGURE 3. Effect of hormone treatment on the percentage of rooting of red clover stem cuttings obtained from parent plants grown under short and long days.

Besides affecting the percentage rooting, hormone treatment affected the degree of rooting, a factor that is not apparent when the data are expressed in terms of percentage cuttings rooted. In general the effect of hormone treatment was to increase the number of roots per rooted cutting. This effect appeared to be independent of previous day-length treatment.

It was shown in Table 1 that the position on the stem from which the cuttings were taken significantly affected the percentage of rooting and that a significant interaction occurred between position of cutting and previous day-length treatment of the parent plant. These effects are shown in the data presented in Table 3 and illustrated in Figure 4. It can be seen from this data that basal cuttings, taken from a parent plant exposed to long-day conditions, root significantly better than medium or upper ones. Position has no effect, however, on the rooting of stem cuttings taken from short-day plants.

DISCUSSION

Red clover is a cross-pollinated crop and consequently highly heterozygous with the result that extreme morphological and physiological variation

TABLE 3.—TRANSFORMED DATA OF MEANS AND DIFFERENCES AMONG MEANS OF ROOTING PERCENTAGES OF BASAL, MEDIUM AND UPPER CUTTINGS

(Main effects and interactions with day-length)

	Means			Differences between means		
	Basal (B)	Medium (M)	Upper (U)	B. – M.	B. – U.	M. – U.
Main effect—						
General means	67.65	55.44	45.90	+ 12.21**	+ 21.75**	+ 9.54*
Interactions—						
Short day	62.32	57.38	58.88	+ 4.94	+ 3.44	– 1.50
Long day	72.98	53.51	32.92	+ 19.47	+ 40.06	+ 20.59**

occurs between plants. This variability greatly complicates studies on the crop since no two plants grown from seed can be expected to react in the same way. Achievement of uniformity through inbreeding is impractical since red clover plants are highly self-sterile. An alternative method of achieving unformity is through the use of clonally propagated single plant lines.

Red clover was found to be easily propagated clonally through the use of crown cuttings taken from plants grown under conditions of short photoperiod. While this procedure yields a high percentage of rooted cuttings, it has the disadvantage of requiring specially light-conditioned plants that take a considerable period of time to prepare and hence is not always practical. The use of stem cuttings presents a possible alternative procedure.

It was found that the clonal lines of red clover tested varied in their ability to root when propagated by stem cuttings. This is not surprising in view of the normal population variation found in red clover. Knight (3) reported that not only different species and genera but even varieties (clonal lines in this experiment) respond differently to the same treatment for vegetative propagation.

The hormone treatment, as applied in this work, resulted in a highly significant decrease in the percentage of rooting of cuttings taken from long-day plants. An increase in the speed of rooting, as evidenced by an increase in the number of roots per rooted cutting after 25 days, resulted from the use of hormone. This did not appear, however, to affect the ultimate establishment and survival of the plants. Nowosad (4) and Scholz and Smidrkol (5), who reported on the advantageous use of hormones in the rooting of red clover cuttings, used only cuttings from plants exposed to long days and based their conclusions in part on the increased speed of rooting from hormone treatment.

Cuttings obtained from plants grown under short days rooted better than those grown under long days. This finding is in agreement with the results of Vekhov and Iljin (as cited in Garner (1)) who obtained increased

*Significant at the 0.05 level.
* Significant at the 00.1 level.

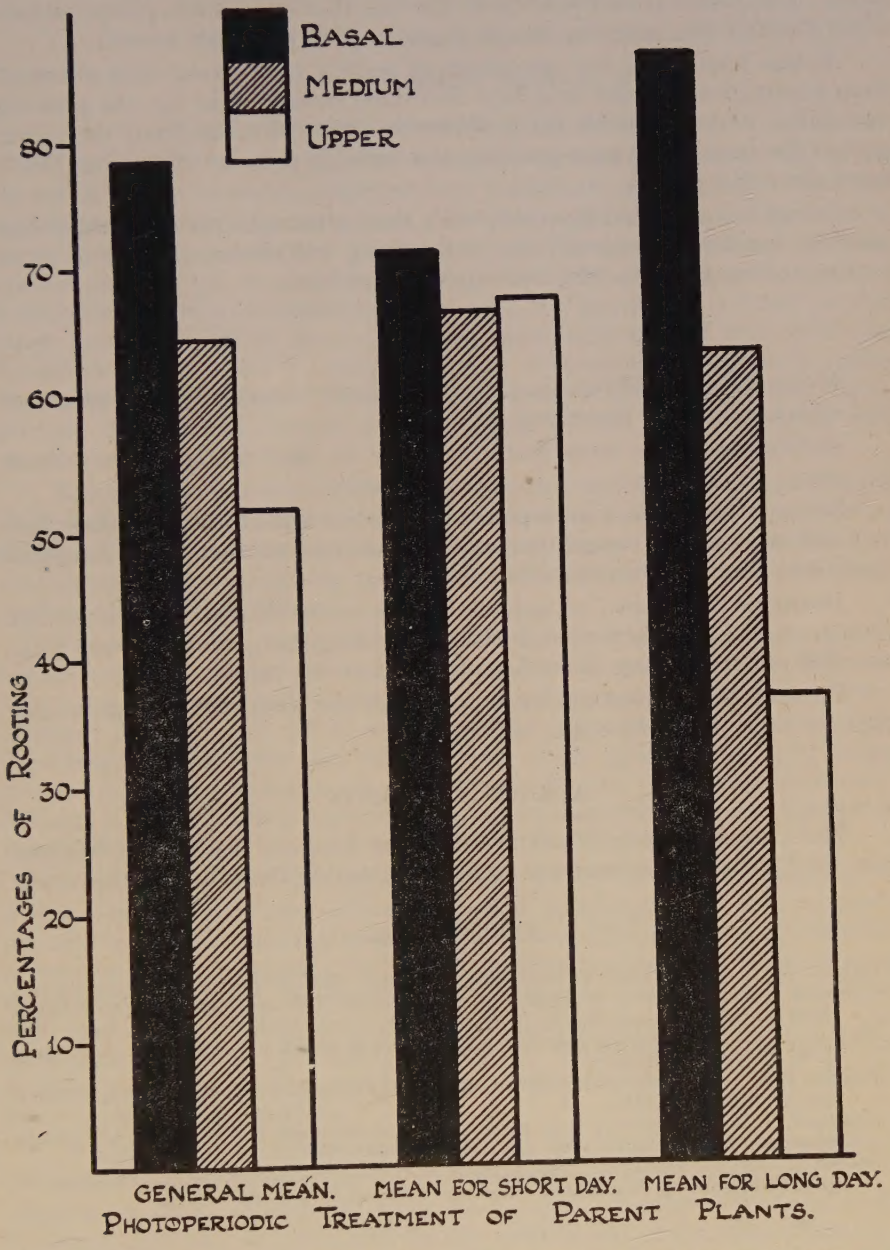

FIGURE 4. The effect on the percentage of rooting of position on the stem from which the cuttings were obtained. Main effect and interaction with day-length.

rooting in species of Cotinus, Acer and Quercus with artificially shortened days. The explanation might lie in the fact that exposure to photo-periods unsatisfactory for flowering results in prolonged vegetative growth.

It was found that the percentage of rooting of stem cuttings obtained from plants grown under long days decreased from base to tip, the greatest variability between clones being shown in cuttings taken from the upper part of the stem. No such gradient was noted in the case of cuttings taken from short-day plants.

It can be concluded from this work that, although crown cuttings offer the best method of vegetatively propagating red clover, the use of stem cuttings offers a satisfactory alternative procedure.

SUMMARY

Methods of clonally propagating red clover through the use of crown and stem cuttings are described.

Individual plants were found to differ in their ability to root from the stem.

Stem cuttings taken from plants exposed to a photo-period below that required for flowering rooted more easily than those exposed to the long-day conditions necessary to induce flowering.

Hormone treatment, as applied in this work, reduced the percentage of cuttings successfully rooted in the case of long-day plants but was without effect on the rooting of cuttings from short-day plants.

Cuttings taken from the basal portion of the stem rooted more readily than did those from the upper portion.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial assistance received from the Quebec Department of Agriculture during the course of this work.

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CHEMICAL COMPOSITION AND DIGESTIBILITY OF FORAGE CROPS GROWN IN CENTRAL SASKATCHEWAN, WITH OBSERVATIONS ON KOCHIA SPECIES

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[Received for publication January 17, 1952]

The quality of roughage in ruminant rations is a major factor in determining the need for supplementary feeds and consequently influences the financial returns to the feeder. However, quality in a forage crop is more readily described than regulated in practice for it is related to plant species and variety, stage of maturity, palatability, kind of cure, chemical composition, and availability of nutrients. Of particular interest among these factors are plant species, chemical composition, and availability of nutrients because they embody the major differences among comparably harvested forage crops. These, together with yield and cultural data, provide more useful criteria for evaluating forages than do yields and chemical composition alone.

Extensive data are available on composition and digestibility of forages (5, 6) but very little information exists pertaining to crops grown and tested under western Canadian conditions. Evaluations of roughages common to this region are needed and the testing of new forage selections should include feeding trials with animals.

The crops most commonly grown for hay in this area include alfalfa (*Medicago sativa*), sweet clover (*Melilotus officinalis* and *Melilotus alba*), oat hay (*Avena sativa*), crested wheat grass (*Agropyron cristatum*) brome grass (*Bromus inermis*) and marsh or lowland hay (predominantly *Carex* with *Fluminea* and *Glyceria* species). Several other grasses currently being tested in western Canada are Canadian wild rye (*Elymus canadensis*), Russian wild rye (*Elymus junceus*) and intermediate wheat grass (*Agropyron intermedium*).

In periods of feed shortages livestock owners are frequently forced to utilize cereal straws and other low-grade roughages. During a recent drought in this province the weed Russian thistle (*Salsola Pestifer*) attracted attention as an emergency feed. Its chemical composition (4) compared favourably with that of alfalfa and established grasses, and its habit indicated good adaptation to drought conditions in the grain belt. Its palatability was low, however, particularly when harvested beyond the optimal stage of maturity, and it was not easily harvested. Cave *et al.* (1) have studied its digestibility.

A report from South Dakota in 1947 by Erickson and Moxon (3) drew the senior author's attention to the desirable forage qualities of *Kochia scoparia*, a plant established there as a weed. Kochia (Burning Bush, Summer Cypress, etc.) is a well-known ornamental in this area which also occurs as a weed in urban waste areas, although the common species in this region is apparently *Kochia childsii*, also known as *K. trichophylla*.[2] The

[1] Associate Professor of Animal Husbandry, Student Assistant, and Associate Professor of Plant Ecology, respectively.

[2] The assistance of C. Frankton, Botanist, Science Service, Dept. Agriculture, Ottawa, is gratefully acknowledged in confirming the identity of the Kochia species as *K. scoparia* (l.) Schrad., and *K. childsii* Hort. ex Mollers also known as *K. trichophylla* Voss.

outstanding characteristics of Kochia, as reported by the South Dakota workers, are drought resistance, grasshopper resistance, leafiness, high seed yields, high protein and carbohydrate content, and yielding ability for hay and silage. It was rated well in palatability tests. In recognition of the fact that these are all paramount features in a dry land forage crop, feeding and cultural tests were conducted respectively by the Departments of Animal Husbandry and Plant Ecology at the University of Saskatchewan in order to evaluate the crop under local conditions and in comparison with better known forages.

This report presents some preliminary cultural data on Kochia species and comparative feed evaluations of thirteen locally grown forages, including several new forage selections, and kochia species at two stages of maturity.

EXPERIMENTAL PROCEDURE

Kochia Seedings

Seed of *Kochia scoparia* was secured from Utah[1] and three separate one-acre plantings were made on the University Farm at Saskatoon, one on April 26, one on November 2, 1949, and one on May 3, 1950. A one-acre plot of *Kochia childsii*[2] was also planted on May 3, adjacent to the latter. The plots were drill-sown at the rate of 10 pounds per acre as near to the surface as possible. The 1950 plantings supplied the forages used in the digestibility studies.

In May 1950 fourteen South Dakota selections of *Kochia scoparia*[3] were sown by the Department of Plant Ecology. Samples of the more promising selections were later taken for chemical analysis. A study of the effects of different rates and dates of seeding was undertaken in which plantings were made on November 1, 1949, and on May 1 and June 6, 1950 with spacings between the rows of 6, 12, 18, 24 and 36 inches, and with the plots randomly allotted on quadruplicated blocks.

Legume and Grass Hays for Digestion Trials

Quantities of alfalfa, sweet clover, crested wheat grass, brome grass, brome grass straw, Canadian wild rye, Russian wild rye and intermediate wheat grass were secured from the Dominion Forage Crops Laboratory test plots at Saskatoon. A mixed sample of white and yellow blossom sweet clover was collected from a roadside stand at the University. Oat hay was obtained from a field adjacent to the kochia plots. The marsh hay was harvested at the Dundurn flats south of Saskatoon and represented a type of hay frequently fed in western Canada.

Most of the forages unless quite dry at time of harvesting were artificially dried (62° C. maximum temperature). A general description of the forages studied with their dates of harvesting is given in Table 1.

When dried, each lot of hay was ground in a hammer-mill fitted with a two-inch screen such that the stem pieces averaged $\frac{3}{4}$ to 1 inch in length,

[1] John K. Olsen, Great Basin Experiment Station, Ephraim, Utah.
[2] Seed obtained from a local seed supply house.
[3] Courtesy M. W. Adams, Agronomy Department, Agr. Exp. Sta., Brookings, S.Dak.

TABLE 1.—GENERAL DESCRIPTION OF FORAGES USED IN DIGESTIBILITY STUDIES

Name	Date harvested 1950	Description
Alfalfa (*Medicago sativa* L.)	July 4	12-18" high, 50% in flower, appearance good, from test plots. Cured artificially for 24 hours.
Sweet clover (*Melilotus spp.*)	July 14	Mixed stand growing wild. *M. officinalis* (l.) Lam., yellow blossom, 16-20" high; *M. alba* Desv., white blossom, 4' high. In full flower. Cured artificially in 24 hours.
Oat hay (*Avena sativa* L.)	Aug. 9	36" high, in late dough stage, beginning to ripen. Cured artificially in 24 hours.
Crested wheat grass (*Agropyron cristatum* (l.) Gaertn.)	July 7	15" high, in full flower, fairly leafy but rather dry in appearance, stored over night in barn loft, curing completed artificially in 10 hours.
Brome grass (*Bromus inermis* Leyss.)	July 7	24-30" high, in full flower, quite leafy, from test plots. Cured artificially for 16 hours.
Brome grass straw (*Bromus inermis* Leyss.)	August 7	From test plots for brome grass seed production. Excellent quality. Field-cured.
Canadian wild rye (*Elymus canadensis* L.)	July 22	20-24" high, in full flower, moderately leafy, stems coarse. Curing completed indoors in 24 hours without heat.
Russian wild rye (*Elymus junceus* Fisch.)	June 29	18-24" high, 50% in flower, appeared coarse and stemmy, from test plots, stored over-night in barn loft in 10" layer, then dried artificially for 11 hours.
Intermediate wheat grass (*Agropyron intermedium* (Host) P.B.)	July 21	24-30" high, in full flower. Rather coarse in appearance. Cured artificially for 16 hours.
Marsh hay (predominantly *Carex* spp.)	July 7	12-18" high. Grown at Dundurn marsh. Field cured, baled. Fair quality. Somewhat over-mature.
Kochia, 1st stage (*Kochia scoparia* (l.) Schrad.)	July 7, 11	16-20" high, pre-bloom, fine stemmed, leafy. Cured artificially in 30 hours.
Kochia, 2nd stage (*Kochia scoparia* (l.) Schrad.)	Aug. 1	36-40" high, stems up to ¼" diameter, leafy. Cured artificially in 40 hours.
Kochia, 1st stage (*Kochia childsii* Hort. ex Mollers)	Aug. 18, 22	12-24" high in a very thick stand. Cured artificially.

or no finer than was believed necessary to discourage sorting by the animals during the feeding tests. Each lot of ground hay was thoroughly mixed prior to sampling for analysis and feeding.

Animals and Management

Four wether lambs from the University flock were confined to digestion cages designed for the separate collection of urine and feces and were treated for parasites with phenothiazine prior to the digestion trials. During the days preceding fecal collection periods, the lambs were allowed out of the cages between morning and evening feedings for exercise. Plain salt was allowed during the tests and water was available except for short periods during feeding when it was removed to avoid wetting the forage being eaten.

Design of Feeding Trials

Since the common latin and lattice square designs often employed in this type of work were not readily adapted to the facilities available and to the number of forages to be tested, a balanced incomplete block design was employed (2). The plan was based on thirteen forages in four replicates with four different forages being tested in each of thirteen periods

TABLE 2.—THE DESIGN OF THE DIGESTIBILITY EXPERIMENT SHOWING THE QUADRUPLICATE TESTING OF THIRTEEN FORAGES WITH FOUR WETHER LAMBS

Periods	Lamb numbers				Key to forages fed	
	I	II	III	IV	Number	Common name
		forage	numbers			
1	1	2	4	10	1	Russian wild rye
2	2	3	5	11	2	Canadian wild rye
3	3	4	6	12	3	Crested wheat grass
4	4	5	7	13	4	Intermediate wheat grass
5	5	6	8	1	5	Brome grass
6	6	7	9	2	6	Alfalfa
7	7	8	10	3	7	Sweet clover
8	8	9	11	4	8	Brome straw
9	9	10	12	5	9	Kochia, 1st stage (*K. childsii*)
10	10	11	13	6	10	Kochia, 1st stage (*K. scoparia*)
11	11	12	1	7	11	Kochia, 2nd stage (*K. scoparia*)
12	12	13	2	8	12	Oat hay
13	13	1	3	9	13	Marsh hay

TABLE 3.—APPROXIMATE FORAGE YIELDS OF PERENNIALS AND ANNUALS AT SASKATOON

Forage crop[1]	Yield/acre (tons dry matter)	Source of data
Alfalfa (Ladak var.)	1.5	
Sweet clover (Arctic var.)	2.0	
Crested wheat grass (Fairway var.)	1.1	
Brome grass (Commercial var.)	1.1	Dom. Forage Crops Lab. 1946-50
Canadian wild rye (Mandan var.)	1.2	
Russian wild rye (S-114 var.)	1.0	
Intermediate wheat grass (Ree. var.)	1.2	
Marsh hay	1.3	Dundurn flats, 1950.
Oat hay	2.7	Animal Husbandry Farm, 1950.
Kochia (*K. scoparia*), 6-in. spacing	5.0[2]	
Kochia (*K. scoparia*), 12-in. spacing	4.9	
Kochia (*K. scoparia*), 18-in. spacing	4.8	Dept. Plant Ecol., sown May 1/50.
Kochia (*K. scoparia*), 24-in. spacing	4.8	
Kochia (*K. scoparia*), 36-in. spacing	3.4	
Kochia (*K. scoparia*), 6-in. spacing	3.9	
Kochia (*K. scoparia*), 12-in. spacing	3.6	
Kochia (*K. scoparia*), 18-in. spacing	3.6	Dept. Plant Ecol., sown June 6/50.
Kochia (*K. scoparia*), 24-in. spacing	3.4	
Kochia (*K. scoparia*), 36-in. spacing	3.1	

[1] Data on the legumes and cultivated grasses derived from the Dominion Forage Crops Laboratory test plots represent stands ranging from one to three years old.

[2] The average heights at maturity (when harvested) for the May 1 plantings were 65, 66, 66, 68 and 64 inches, respectively for the spacings shown. The corresponding heights for the June 6 plantings were 58, 57, 59, 56 and 57 inches.

(Table 2). This design has been given an efficiency factor of 0.81 representing the lower limit of efficiency as compared to completely randomised blocks; but a higher rating might be expected in this experiment because the differences between periods (changes in digestive abilities of sheep and changes in nutritive value of the forages held in freezing storage) should have been small in relation to the intra-period variations.

FIGURE 1. Kochia plants growing in plots at Saskatoon, 1950.

The digestion trials were conducted in the conventional manner. A 5-day preliminary period was employed during which the animals became accustomed to their respective feeds and constant daily intakes depending on appetite. Following the preliminary periods quantitative fecal collections were made daily for 10 days. One-tenth of the daily feces was saved in 0.1N sulphuric acid with a few drops of toluene, and a similar aliquot saved by drying was subsequently analysed for crude fibre, ether extract, ash and certain other components. The liquid fecal sample was analysed for total nitrogen following thorough blending.

RESULTS AND DISCUSSION

General Observations

It is not the intention of this report to present in detail the agronomic performance of the crops used except in the case of kochia. Inasmuch as this crop is new in this area, general observations on its performance are included.

Some general observations regarding the culture and characteristics of kochia seem worthy of presentation. From the feeding standpoint the crop was considered favourable. It was very leafy well down to the base of the stem despite its dense manner of growth and during the earlier stages at least had the outward appearance of a desirable forage crop. Later as the plants grew beyond about 3 feet in height, the main stems became rather hard and woody which rendered them less suitable as a dry-cured roughage; but their acceptability as an ensilage crop remains to be explored. It is apparent, however, that more research is needed on the cultural aspects of growing kochia in order to obtain more uniform stands as well as to improve seed maturation which has proven to be a problem in this area.

TABLE 4.—CHEMICAL COMPOSITION OF *Kochia scoparia* AT SEVERAL STAGES OF MATURITY

Sample number	Height	Description	Moisture	Crude protein	Crude fat	Crude fibre	Ash	Nitrogen-free extract	Carotene
	(inches)		%	%	%	%	%	%	mg./lb.
19	24	Very fine, leafy	5.0	21.0	1.5	15.2	15.5	41.8	(1)
14	36	Very fine, leafy	5.0	17.1	1.4	19.7	12.6	44.2	20.8
15	48	Heavy main stem, leafy	5.0	15.6	1.0	21.1	10.9	46.3	17.2
Average of plants 36 to 48 inches high			5.0	17.9	1.3	18.7	13.0	44.1	19.0
16	54	Coarse stems, leafy	4.9	7.9	1.0	21.3	9.2	55.7	4.3
17	66	Coarse stems, leafy	4.9	9.6	0.9	22.4	9.2	53.0	5.9
20	72	Coarse single plant	5.5	7.7	1.2	19.5	10.1	56.0	9.4
21	72	Coarse single plant	4.8	11.5	0.9	23.9	10.6	48.3	13.8
Average of plants 48 to 72 inches high			5.0	9.2	1.0	21.8	9.8	53.3	8.3
Average of 7 South Dakota selections grown at Saskatoon. Plants 70 inches tall			4.4	14.4	1.1	33.1	11.7	35.2	8.8

(1) Not analysed.

Since the final appraisal of a forage crop must include data on both yields and nutritive value, it has been considered worth-while to present the available yield data on the crops subjected to digestibility studies (Table 3). Most of the yields are drawn from the records of the Dominion Forage Crops Laboratory for the years 1946-1950. Data for oat and marsh hay and for kochia were obtained from the Departments of Animal Husbandry and Plant Ecology respectively. Because the yields presented were not all derived from strictly comparable studies, only general comparisons within this table are permissible. For instance, in contrast to data from the Dominion Forage Crops Laboratory tests, the yields for kochia and marsh hay represent crops harvested at a relatively mature state. The kochia was cut at a stage comparable to the second stage of *K. scoparia* used in the digestion studies, and it is therefore difficult to estimate yields of kochia if harvested at 2 feet or less in height when it would possess a more desirable texture and chemical composition.

Chemical Composition of Forages

Samples of kochia grown in 1949 in 1-acre plots and taken at various stages of maturity were analysed for protein, ether extract, crude fibre, ash and carotene. The compositions of these and of several South Dakota selections are presented in Table 4. The forage samples were dried in a building maintained at 75-80° F. which accounts for the low moisture percentage. Of special interest, however, in these data are the high levels of protein, particularly in kochia below 48 inches tall, where the average content of protein was 17.9 per cent (range: 15.6 – 21.0). The level of protein in plants up to 72 inches in height remained surprisingly high in view of the coarse appearance of the plants. The difference in protein content of samples 20 and 21 may be related to leafiness and/or density of stand as these plants grew in rather isolated locations where seedling emergence was poor. Despite a degree of coarseness, the percentage of crude fibre did not exceed that commonly found in grass hays, and the cured samples contained high levels of carotene.

In Table 5 are given the proximate analyses of the forages used in the digestibility studies and otherwise described in Table 1. It will be noted that kochia (*K. scoparia*) cut when 16-20 inches high was similar in composition to the 24-inch sample analysed the previous year, and contained even more protein than did the legume hays. Likewise the crude fibre content was comparatively low.

The ash content of kochia is of some interest in that the amount ranged from 9.2 to 16.7 per cent of the sample, considerably exceeding the ash content of the other roughages studied. Possibly associated with this is the fact that whenever kochia was fed during the digestion trials the sheep involved drank more water and voided feces with higher water content than was common with the other forages. Further work is needed on the composition of the ash particularly as it might affect the mineral balances of animals fed kochia over prolonged periods.

Of the newer grasses, Canadian wild rye, Russian wild rye and intermediate wheat grass, the last one appeared to be inferior from the stand-

TABLE 5.—CHEMICAL COMPOSITION AND DIGESTIBILITY (IN PARENTHESES) OF THE COMPONENTS OF THE FORAGES. ALL VALUES EXPRESSED AS PERCENTAGES

Forage	Dry matter	Crude protein	Crude fibre	Nitrogen-free extract	Crude fat	Ash
Alfalfa	86.8 (67)	17.2 (80)	22.3 (49)	37.0 (74)	2.6 (49)	7.7
Sweet clover	84.5 (64)	16.1 (80)	22.2 (40)	37.6 (71)	2.4 (50)	6.2
Oat hay	86.5 (59)	9.3 (70)	25.5 (55)	41.9 (62)	2.9 (67)	6.9
Crested wheat grass	88.4 (59)	9.9 (66)	17.9 (43)	52.6 (69)	2.4 (44)	5.6
Brome grass	88.7 (63)	11.9 (70)	26.0 (68)	41.8 (64)	2.7 (55)	6.3
Brome grass straw	87.6 (57)	8.0 (57)	28.4 (63)	42.3 (58)	1.9 (33)	7.0
Canadian wild rye	88.3 (62)	10.6 (67)	20.0 (53)	49.4 (68)	1.9 (25)	6.4
Russian wild rye	87.2 (60)	11.7 (73)	19.5 (51)	47.8 (64)	1.9 (34)	6.3
Intermediate wheat grass	90.4 (60)	8.8 (66)	31.0 (64)	42.6 (61)	2.2 (47)	5.8
Marsh hay	87.1 (54)	5.9 (39)	29.2 (62)	44.5 (57)	2.1 (48)	5.4
Kochia scoparia, 1st stage	86.9 (70)	18.7 (83)	17.1 (49)	32.3 (68)	2.1 (67)	16.7
Kochia scoparia, 2nd stage	87.4 (56)	9.8 (69)	31.1 (46)	34.5 (57)	1.3 (40)	10.7
Kochia childsii, 1st stage	87.3 (54)	9.4 (62)	29.2 (46)	36.9 (55)	1.8 (47)	10.0
Necessary difference in digestibility	(3.5)	(4.1)	(9.5)	(7.9)	(20.7)	—

points of protein and fibre. This might be due in part to differences in stage of maturity at harvesting; hence, further work is necessary before the significance of such differences can be evaluated.

Marsh hay contained the least protein of all the hays studied and while it was harvested at a later stage of maturity than the cultivated grasses, it was representative of much of the lowland hay secured by farmers in Western Canada.

Digestibility of Forage Constituents

The digestibility coefficients for the various feed components were statistically analysed and the adjusted average coefficients have been presented in Table 5 together with the differences required for significance at $P = 0.05$. It is readily apparent that there are important differences in digestibility between forages.

The legumes, which contained the higher levels of crude protein, had highly digestible protein (80 per cent). Kochia (*K. scoparia*) in its earlier stages yielded a protein digestion coefficient of 83 per cent, thus ranking it with the legumes in this respect. The digestion coefficients for oat hay, crested wheat grass, brome grass hay, Canadian wild rye, intermediate wheat grass and *Kochia scoparia* (second stage) ranged between 65 and 70 per cent, but Russian wild rye protein was 73 per cent digestible and the coefficients for brome straw, *Kochia childsii* and marsh hay varied between 62 and 38 per cent.

The combined effects of digestibility and protein contents are illustrated in Figure 2 from which it is evident that the two legumes (alfalfa and sweet clover) and kochia (*K. scoparia*) in the earlier stages rank well above the grasses and other kochia samples in digestible crude protein (DCP) contents.

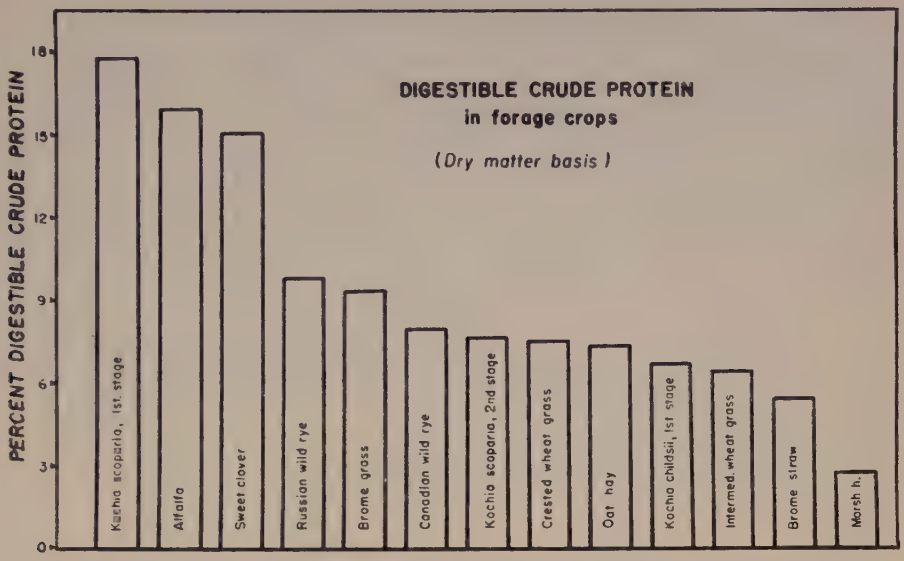

FIGURE 2. Content of digestible crude protein in the dry matter of forage crops.

From the standpoint of practical live stock feeding the DCP values represent the outstanding differences among these forages when used for hay. Even though significant differences exist among the digestion coefficients of component fractions (crude fibre, nitrogen-free extract and crude fat) the differences in Total Digestible Nutrients (TDN), though often significant, are of smaller magnitude than the DCP differences. The majority of hays produced TDN values ranging from 55 to 65 per cent (Table 6).

TABLE 6.—DIGESTIBLE CRUDE PROTEIN (DCP) AND TOTAL DIGESTIBLE NUTRIENT (TDN) CONTENT OF FORAGES[1], TOGETHER WITH AMOUNTS OF DRY MATTER CONSUMED PER DAY DURING THE DIGESTION TRIALS

Forage	DCP	TDN	Dry matter consumption
	%	%	lb./day
Alfalfa	16	64	2.4
Sweet clover	15	61	2.2
Oat hay	7	59	2.2
Crested wheat grass	8	58	2.1
Brome grass	9	63	2.3
Brome grass straw	5	56	2.1
Canadian wild rye	8	61	1.6
Russian wild rye	10	59	2.0
Intermediate wheat grass	6	59	2.0
Marsh hay	3	54	2.1
Kochia scoparia, 1st stage	18	57	1.9
Kochia scoparia, 2nd stage	8	48	1.8
Kochia childsii, 1st stage	7	47	1.8
Necessary difference	0.5	4.5	—

[1] Dry matter basis.

It is evident from the standpoint of TDN that kochia hays tend to be inferior. The only values below 50 per cent TDN were derived from second-stage *Kochia scoparia* and from the *Kochia childsii* sample. The early cutting of Kochia failed to equal the legume hays in TDN but compared quite well with the grass hays. Recalling that the ash content of kochia (cut early) was double that of alfalfa, it is possible that this factor alone could account for the differences in TDN. Calculations showed equal digestibility of organic matter in these two hays (68 per cent) and, further, that the TDN contents expressed on the basis of ash- and moisture-free samples were nearly identical: kochia, 68; alfalfa, 70. These comparisons further demonstrate that the important energy-yielding nutrients in the kochia (cut early) and alfalfa are equally available but because of the high ash content of kochia about 14 per cent more would have to be consumed to yield the same weight of TDN. It is therefore interesting to note the levels of consumption obtained on the various forages during the digestion studies. No palatability trials, in which animals were allowed their choice of forages, were conducted. However, admitting that palatability is an important consideration in forage crops, it may be of somewhat more importance in practice to know something of the consumption levels obtainable when animals have no choice and must accustom themselves to feeds they might not voluntarily select. In Table 6 are shown the average daily intakes of dry matter during the 10-day collection periods. These figures, however, may not compare closely with others derived after longer periods of adjustment but they do indicate that initial palatability, at least, of kochia is not as high as with legume hays, brome grass or oat hay. The intake of Canadian wild rye proved the lowest in the test.

In summarizing the results of this study, it may be said of the common forage crops that, as usual, the legumes are heavier yielding and more nutritious forages than the cultivated grasses. Marsh hay yielded reasonably well but produced a feed of rather low nutritive value, particularly with respect to protein. The results thus far with kochia appear promising. Forage yields of this crop have been far in excess of those obtained from other crops studied although strictly comparable tests have not been conducted. Furthermore, its chemical composition and nutritive value (as determined by digestion studies) have ranked it with alfalfa, provided it was harvested reasonably early. Remaining to be assessed are the nutritional significance of the high mineral content in kochia, the reasons for delayed seed maturation in this region, and causes of uneven germination or seedling emergence, among other factors.

SUMMARY

Chemical and digestibility data, together with a few general observations on cultural aspects of Kochia species, have been presented for thirteen forage crops grown in central Saskatchewan. The crops studied were alfalfa, sweet clover, oat hay, crested wheat grass, brome grass, brome grass straw, Canadian wild rye, Russian wild rye, intermediate wheat grass, marsh hay, kochia (*K. scoparia*) at two stages of maturity and *Kochia childsii* at an early stage of maturity. The important differences between the various roughages are discussed.

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UPTAKE BY PLANTS OF LABELLED PHOSPHATE FROM NEUTRON-IRRADIATED CALCIUM PHOSPHATES

I. UPTAKE BY SEEDLINGS FROM SOLUTION CULTURES[1]

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The authors have presented evidence (1, 2, 3) that neutron bombardment of materials containing calcium phosphate may result in the occurrence in the bombarded substance of phosphorus-32 in the ortho-, pyro-, meta-, and hypophosphate forms, the proportions of these forms present differing with the nature of the material irradiated. It seems possible that the conditions of neutron bombardment also may have an influence in this respect.

Martin and Russell (6) have reported that neutron-irradiation of disodium phosphate resulted in the accumulation by plants of the phosphorus-32 produced at a faster rate than the accumulation of phosphorus-31. Fried and MacKenzie (4) have noted a similar phenomenon in relation to uptake from neutron-irradiated rock phosphate. Such observations indicate that estimates of the uptake of fertilizer phosphorus by plants which are based on the phosphorus-31 to phosphorus-32 ratio in a fertilizer material, in which the phosphorus-32 source has been neutron-irradiated, must be accepted with some reserve. The chemical form or forms in which the phosphorus-32 occurs may influence the result. This possibility has been explored in the experiments described in the present report.

EXPERIMENTAL METHODS

Seedlings of Montcalm barley, Banner oats and Horton rye were employed in the estimation of plant uptake. The Thornton modification (7) of the Neubauer technique was used, except that the water was supplied as a spray rather than through a central tube. The phosphorus content of the seeds was calculated from the weight of the 100 selected-seed samples planted, experiment having shown a high correlation of seed weight to phosphorus content in the case of the grain samples used in this investigation.

The containers used were enamelled cans 20.8 cm. in diameter and 15.8 cm. deep. Experiment indicated that these cans were non-retentive of phosphorus. One hundred grams of acid-washed quartz sand were placed in the can and the fertilizer materials distributed over this in a ring 5 cm. in diameter. In experiments employing a buffer one gram of the buffer salt plus 60 ml. of distilled water were added at this point, the mixture stirred and the pH measured; the radioactivity of the bombarded materials was not sufficient to interfere with pH measurements using the glass-calomel electrode assembly. When necessary the pH was adjusted to the required value by addition of 2N ammonium hydroxide or 2N acetic

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acid solution. A second 100-gram portion of sand then was added and the seeds distributed evenly over the surface. The seeds were covered with 200 grams sand and the water content brought to 70 ml. per can. After covering with watch glasses the cultures were placed in an incubator room at 22° C. and 50 per cent relative humidity. They were illuminated for 12 hours daily, the source being a bank of fluorescent lamps. The cultures were weighed daily and the moisture-loss replaced by addition of distilled water as a spray. When the seedlings reached a height of 2.5 cm. the watch glasses were removed.

At the end of the 15th day of incubation each culture was emptied into a sieve through which the sand was washed, using 200 ml. of water as a spray. The seedlings then were sprinkled with "Dreft" and sprayed with an additional 200 ml. of water to remove any phosphatic material adhering to the plant surfaces.

The washed seedlings were transferred to tared 125 ml. Erlenmeyer flasks and dried to constant weight at 100° C. The weight of flask plus seedlings was recorded, 30 ml. concentrated nitric acid added, and the mixture digested. After most of the plant material had been decomposed, the solution was taken nearly to dryness, 20 ml. of a solution containing 2 ml. of reagent grade perchloric acid and 2 gm. of ammonium persulphate added, and the mixture heated to strong evolution of white fumes. The solution was transferred to a 100 ml. volumetric flask and the latter filled by decantation of successive small portions of distilled water from the digestion flask. Any sand remaining after these decantations was dried and weighed, the weight found being used to correct the apparent weight of the seedlings obtained previously.

A 50-ml. portion of the solution obtained from the seedlings was used for measurement of radioactivity after conversion of the phosphorus to magnesium ammonium phosphate hexahydrate. The remainder of the solution was used for the estimation of total phosphorus by the colorimetric procedure of Gerritz (5).

TABLE 1.—DESCRIPTION OF RADIOACTIVE MATERIALS

Material	Total P^{32}	Orthophosphate P^{32}		Remarks
	C/m per mgm. P.	C/m per mgm. P.	Per cent of total P-32	
Superphosphate N.R.C. 510-1	4877 (63.4)	1900 (24.7)	39.0 39.0	Commercial product of Canadian Industries Ltd. Fraction passing 10—refusing 40-mesh sieves.
Monocalcium phosphate N.R.C. 510-2	1103 (11.5)	341 (3.8)	30.9 (33.0)	Commercial product of Merck and Company.
Monocalcium phosphate	822 (13.1)	370 (5.9)	45.0 45.0	Commercial product of Baker and Adamson.

Radioactive assay of the forms of phosphorus present in the bombarded materials was made by the carrier-precipitation techniques described previously (3).

The radioactive materials used and the activities applied experimentally are described in Table 1. The readings in parentheses were taken 90 days after the first ones were recorded.

The data of Table 1 indicate that the fraction of the phosphorus-32 estimated to be in the orthophosphate form remained essentially constant during storage of these materials in the solid state.

Two seedling-uptake experiments were carried out. In the first of these the plants were grown in unbuffered sand cultures; in the second an attempt was made to regulate the pH of the media by addition of buffering salts.

EXPERIMENTAL RESULTS AND DISCUSSION

Uptake from Unbuffered Sand Cultures

In this experiment the irradiated phosphatic materials were added at the rate of 0.002 gm. of total phosphorus per culture. Each culture also received 0.020 gm. of potassium sulphate. All treatments were duplicated. The results obtained are shown in Table 2.

TABLE 2.—UPTAKE BY SEEDLINGS FROM UNBUFFERED SAND CULTURES

Material	Radioactivity of material c/m.		Uptake by 100 seedlings (c/m.)			Total phosphorus uptake (mg.)		
	Total	Ortho-phosphate	Barley	Oats	Rye	Barley	Oats	Rye
Superphosphate	9754	3800	3775	3752	3700	1.95	1.92	1.88
N.R.C. 510-1			3768	3786	3716	1.96	1.98	1.84
Monocalcium phosphate	2207	683	724	728	731	2.00	2.02	2.12
N.R.C. 510-2			721	717	720	1.92	1.96	1.94
Monocalcium phosphate	1645	740	741	745	736	2.05	2.05	2.02
N.R.C. 510-3			742	738	733	2.03	1.95	1.96

Inspection of the data obtained shows that, in each instance, the radioactivity of the seedling phosphorus corresponds closely to that of the fraction of the phosphorus-32 estimated by analysis to be present in the orthophosphate form. Further, essentially all the phosphorus-31 supplied was taken up by the seedlings, with the possible exception of the uptake by rye seedlings from superphosphate.

Uptake from Buffered Sand Cultures

In this experiment Montcalm barley seedlings only were used, the amount of irradiated material added was 0.100 gm. per culture corresponding to 10.0, 27.4 and 26.0 mg. of total phosphorus for samples 510-1, 510-2 and 510-3 respectively, and the cultures were buffered at varying pH values by addition of 1.0 gm. of ammonium acetate to each, plus such amounts of 2N ammonium hydroxide or 2N acetic acid as were required to

TABLE 3.—UPTAKE BY SEEDLINGS FROM BUFFERED SAND CULTURES

Material	Radioactivity of material (c/m.)		Uptake of P^{32} at pH indicated (c/m.)					Uptake of total phosphorus at pH indicated (mg.)				
	Total	Ortho-phosphate	3.5	4.6	6.0	7.0	8.0	3.5	4.6	6.0	7.0	8.0
Superphosphate N.R.C. 510-1	634	247	—	148	—	240	247	—	3.8	—	6.7	6.2
			—	262	—	262	238	—	6.7	—	6.2	6.4
			405	—	—	—	—	7.9	—	—	—	—
			403	—	—	—	—	7.8	—	—	—	—
			427	—	—	—	—	8.4	—	—	—	—
			415	—	—	—	—	8.2	—	—	—	—
Monocalcium phosphate N.R.C. 510-2	316	104	—	(205)	146	171	—	—	(26.5)	15.7	21.2	—
			—	(188)	162	176	—	—	(25.2)	17.5	19.9	—
Monocalcium phosphate N.R.C. 510-3	340	153	—	140	158	—	—	—	19.1	21.3	—	—
			—	138	152	—	—	—	18.2	21.8	—	—

give the desired pH. Additional cultures were buffered at pH 3.5 with ammonium sulphate and at pH 4.6 with ammonium nitrate respectively. Each culture also contained 0.050 gm. potassium sulphate. The results obtained are recorded in Table 3, the values in parentheses being those obtained with ammonium nitrate.

Examination of the data in Table 3 shows that the results were much more variable than those obtained in the previous experiment. It indicates also that the pH effect on uptake apparently was small, except in the case of superphosphate buffered at pH 3.5 with ammonium sulphate. The data also indicate that, in respect of uptake of phosphorus-32 from cultures buffered with ammonium acetate, samples 510-1 and 510-3 behaved similarly and differently from sample 510-2. Thus, the uptake of phosphorus-32 from 510-1 and 510-3 corresponds (as in the previous experiment with unbuffered sand cultures) rather closely with the amount of radioactive orthophosphate found by analysis. On the other hand, the uptake from sample 510-2 exceeds considerably the estimated orthophosphate phosphorus-32. An experiment in which these irradiated materials were allowed to stand for 32 days in contact with ammonium acetate buffer appeared to shed some light on this difference in seedling-uptake behaviour. Thus, during such standing the amount of phosphorus-32 estimated to be in the orthophosphate form increased from about 31 per cent to approximately 80 per cent in the case of sample 510-2. The corresponding changes for samples 510-1 and 510-3 were from 39 to 47, and 45 to 62 per cent respectively in content of the orthophosphate form of phosphorus-32 under these conditions. These results appear to support the view that orthophosphate is more readily taken up by seedling plants than other chemical forms of phosphorus-32.

The results obtained when seedlings were grown in unbuffered sand cultures indicated that phosphorus-32 in the orthophosphate form might be used as a suitable indicator of uptake of fertilizer phosphorus from neutron-irradiated calcium phosphates. Those obtained for sand cultures buffered with ammonium salts, together with the observation that the extent of conversion of other forms of phosphorus-32 to orthophosphate was variable, discounted this view. In order that the uptake of radioactive phosphorus from a labelled fertilizer may serve as a suitable index of the intake of fertilizer phosphorus by plants phosphorus-31 and phosphorus-32 must be accumulated at a constant ratio. The average ratios found in the buffered sandculture experiment are given in Table 4.

TABLE 4.—RATIOS OF PER CENT UPTAKE OF P^{31} TO PER CENT UPTAKE OF P^{32} AT pH VALUES INDICATED

Materials	pH Values of cultures				
	3.5	4.6	6.0	7.0	8.0
Superphosphate N.R.C. 510-1	(1.3)	2.1	—	1.6	1.7
Monocalcium phosphate N.R.C. 510-2	—	(1.5)	1.2	1.3	—
Monocalcium phosphate N.R C. 510-3	—	1.8	1.8	—	—

In calculating the ratios of Table 4 the total phosphorus uptake of the seedlings was expressed as a percentage of the total phosphorus supplied, and the counts per minute given by the radioactive phosphorus in the seedlings as a percentage of the total counts per minute given by the irradiated material added to the culture; then the former was divided by the latter. Ammonium sulphate was the salt added to the cultures giving the ratio 1.3, ammonium nitrate to those giving 1.5; the others received ammonium acetate. The data so obtained show that, under the experimental conditions employed, the ratio was far from constant. Calculation showed that the ratio, uptake of phosphorus-31 to uptake of orthophosphate phosphorus-32, based on the estimated content of phosphorus-32 in the material added to the culture, was even more variable, the values ranging from 0.5 to 1.8.

SUMMARY

Evidence has been presented which indicates that seedling plants of barley, oats and rye absorb the orthophosphate form of phosphorus-32 preferentially from sand cultures containing neutron-irradiated calcium phosphates, and that the ratio, per cent uptake of phosphorus-31 to per cent uptake of phosphorus-32, is not a constant under the experimental conditions employed.

ACKNOWLEDGMENTS

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UPTAKE BY PLANTS OF LABELLED PHOSPHATES FROM NEUTRON-IRRADIATED CALCIUM PHOSPHATES

II. UPTAKE BY SEEDLINGS FROM SOIL-SAND CULTURES[1]

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Previous papers (2, 3, 4) have reported the analysis of neutron-irradiated calcium phosphates for chemical forms of phosphorus-32 and the uptake of phosphorus from such materials by seedling plants grown in sand cultures. The present communication presents data on seedling uptake of phosphorus from soil-sand cultures.

EXPERIMENTAL MATERIALS AND METHODS

The irradiated phosphates used were described in the preceding paper of this series (4). The soils employed were Rideau clay (5), Nappan sandy clay loam (8), St. Anicet silty clay loam (6) and Greensboro loam (1). Bulk samples of these soils, unlimed, and limed at the rate of 6,000 pounds of $CaCO_3$ per 2,000,000 pounds of soil, were maintained at about 50 per cent of moisture-holding capacity for two months prior to air-drying and experimental use. The pH values of the soils as used, and their easily-soluble phosphorus contents (7) in the unlimed condition, are given in Table 1.

Table 1.—Soil characteristics

Soil	pH Value		Easily-soluble phosphorus (P) p.p.m.
	Unlimed	Limed	
Rideau clay	6.5	7.8	17
Nappan sandy clay loam	4.9	5.5	12
St. Anicet silty clay loam	6.2	7.6	37
Greensboro loam	4.5	5.8	9

Phosphorus uptake was measured by a modified Neubauer technique using seedlings of Banner oats for Greensboro loam and of Montcalm barley for the other three soils. The soil treatments made were as follows: No lime versus lime at the rate indicated, no phosphorus versus phosphorus from three neutron-irradiated calcium phosphates all applied at the rate of 0.002 gm. total phosphorus per culture, and no potassium versus potassium

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sulphate at the rate of 0.020 gm. per culture. These treatments were applied alone and in combination. All treatments were duplicated, in the case of the Greenboro soil triplicated, in a randomized block design. The no-phosphorus treatment is indicated by P_0; P_1, P_2 and P_3 indicate applications of superphosphate N.R.C. 510-1, monocalcium phosphate N.R.C. 510-2, and monocalcium phosphate N.R.C. 510-3, respectively.

In preparing the cultures 50 gm. acid-washed quartz sand mixed with 100 gm. of 2-mm. soil was placed in cans of the type indicated in the preceding paper (4). When fertilizers were added these were applied next. P_2 and P_3, also potassium sulphate, were added as solutions in a narrow annular ring near the centres of the containers. P_1 was applied as a solid in a similar manner. One hundred selected seeds were distributed evenly over the surface of the soil-sand mixture, covered with 350 gm. of acid-washed quartz sand, and 80 ml. distilled water added. The cultures then were transferred to the incubator-room, in which the conditions described in the preceding paper (4) were maintained. After 16 days' incubation the seedlings were separated from the culture media and analysed as described earlier (4).

EXPERIMENTAL RESULTS AND DISCUSSION

The fertilizer-phosphorus intake was assessed on the basis of the assumption that only the orthophosphate form of phosphorus-32 was taken up by the seedlings, previous experiments (4) having indicated a preferential uptake of this chemical form of phosphorus-32 from neutron-irradiated calcium phosphates by seedlings of the cereal grains. Statistical analysis of the data obtained indicated no significant differences in the uptake of the fertilizer-phosphorus from the three irradiated materials employed. This, despite the fact that the amount of phosphorus-32 estimated to have been added to the soils in the orthophosphate form varied considerably, namely, in the ratios 2.38 : 1.00 : 1.47 : for P_1, P_2, and P_3, respectively. Neither did liming or the application of potassium sulphate produce definitely significant effects on the intake of fertilizer-phosphorus. In fact, the principal result of the experiment was to demonstrate that the properties of the soils used dominated both the growth of the seedlings and their phosphorus uptakes. This point is illustrated by the data in Table 2, in which the results obtained for the three phosphorus treatments are averaged and compared with the mean values for the no-phosphorus cultures. The average deviations from the mean values are given in parentheses. The estimated uptakes of fertilizer-phosphorus are given in columns under F, those for total phosphorus uptakes in columns under T.

Inspection of the data of Table 2 shows that, under the experimental conditions employed, seedlings grown on the Rideau and the Nappan soils showed a high uptake of soil phosphorus relative to fertilizer phosphorus as compared with seedlings grown on the St. Anicet and the Greensboro soils. Possibly this behaviour may be related to vigour of seedling development. Thus, the mean dry weights of plant material harvested per culture were slightly more than 2 grams for the Rideau and Nappan soils and approximately 1.70 and 1.86 for the St. Anicet and Greensboro soils, respectively.

TABLE 2.—COMPARISON OF PHOSPHORUS INTAKE FROM SOILS (MG. P)

Soil	Phosphorus treatments Other treatments	Nil		Potassium		Lime		Potassium plus lime		Mean values total phosphorus uptake
		F	T	F	T	F	T	F	T	
Rideau	P_0	— —	5.38 (0.87)	— —	5.17 (1.00)	— —	7.25 (0.11)	— —	6.20 (0.06)	6.00
	Mean of P_1, P_2, P_3	0.74 (0.12)	6.12 (0.20)	0.78 (0.14)	6.41 (0.37)	1.07 (0.25)	7.74 (0.84)	1.26 (0.31)	8.31 (0.38)	7.15
Nappan	P_0	— —	1.60 (0.25)	— —	2.22 (0.20)	— —	2.77 (0.27)	— —	2.50 (0.40)	2.27
	Mean of P_1, P_2, P_3	0.25 (0.09)	2.41 (0.49)	0.27 (0.08)	2.63 (0.22)	0.25 (0.08)	2.79 (0.45)	0.30 (0.08)	2.86 (0.28)	2.67
St. Anicet	P_0	— —	0.75 (0.35)	— —	1.30 (0.09)	— —	1.57 (0.24)	— —	1.80 (0.19)	1.36
	Mean of P_1, P_2, P_3	0.50 (0.11)	1.34 (0.33)	0.53 (0.11)	2.29 (0.57)	0.51 (0.12)	1.83 (0.52)	0.53 (0.16)	1.95 (0.27)	1.85
Greensboro	P_0	— —	1.69 (0.66)	— —	2.88 (0.40)	— —	4.05 (0.45)	— —	2.84 (0.83)	2.87
	Mean of P_1, P_2, P_3	0.64 (0.15)	3.09 (0.90)	0.67 (0.17)	2.73 (0.58)	0.88 (0.07)	4.62 (0.64)	0.88 (0.24)	3.77 (1.06)	3.55

Availability of soil phosphorus often has been related to soil pH. In the present experiment, however, the seedling uptakes from the Rideau and the St. Anicet soils differed widely in spite of the fact that the pH values of these soils were similar in both the limed and the unlimed conditions (Table 1), and were within a pH range in which the availability of soil phosphorus commonly is regarded as being relatively good. Further, the St. Anicet soil with the higher easily-soluble phosphorus content (Table 1) gave much the smaller seedling uptake.

SUMMARY

An attempt has been made, using a seedling technique, to evaluate the uptake of soil and of fertilizer phosphorus from four soils treated with three neutron-irradiated calcium phosphates. Definitely significant differences in phosphorus uptake attributable to source of fertilizer phosphorus, liming, or to the addition of potassium sulphate, were not found. The results obtained were dominated by the properties of the soils used. Further work will be required to establish the nature of the soil properties involved.

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HOARY CRESSES IN CANADA WITH PARTICULAR REFERENCE TO THEIR DISTRIBUTION AND CONTROL IN ALBERTA[1]

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INTRODUCTION

Several of Canada's worst weeds have been inadvertently introduced from abroad and allowed to spread from small and inconspicuous beginnings until they have become major threats to economical crop production in various parts of the country. Hoary cress is one of these weeds and probably represents a more serious menace than is commonly realized.

The history of its spread in other countries provides ample evidence that wherever this weed occurs it should be met with intensive efforts to effect its control or eradication. Hoary cress is considered by Blackman and Holly (4) to be the only serious foreign weed menace in England. Fifty years ago it was one of the rarest plants in that country, but has spread rapidly over southeast England and in many places has been recognized as an important weed for over thirty years (34). In Australia hoary cress arrived in impure agricultural seed, in fodder, and in ships' ballast. It is now spread over Victoria where it is considered to be the worst weed (26) and is widely distributed in South Australia (27). Representative literature from South America (18) and United States (15, 16, 29) likewise emphasizes the association of spread and persistence of hoary cress with major agricultural losses.

The purpose of this paper is to show the present status of hoary cress in Canada, and, from survey observations in Alberta, to discuss the biology of this weed, methods of control practised, and the measure of success attained by these methods. Three different hoary cresses are represented in Alberta and certain other provinces of Canada and part of the biological data concerns differences in adaptation and behaviour of these three types of plants. The field work involved was carried out by one of the authors* during a period of about five weeks in the summer of 1950.

This study stems from a survey in the previous year by M. A. Melnyk, who prepared maps showing the location and degree of infestation of seven persistent perennials in Alberta from the records kept by weed inspectors, field supervisors, and others (22). From this compilation it was apparent that hoary cress, with its large acreage in Alberta in comparison with that in other provinces, presented a problem that could be most readily dealt with in Alberta.

The work in both years was part of a larger study of persistent perennial weeds arranged in 1949 as a co-operative project between the Federal Department of Agriculture and the Provincial Departments of Agriculture in Alberta, Saskatchewan and Manitoba.

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THE HOARY CRESSES AND THEIR DISTRIBUTION IN CANADA

The occurrence of three hoary cresses in North America has been reported by Bellue (3), and confirmed by various other authors (11, 19). Rollins (28) clarified the taxonomy of this group and emphasized the close relationships of the three entities by the following nomenclature now commonly adopted: *Cardaria draba* (L.) Desv., heartpodded hoary cress; *Cardaria draba* (L.) Desv. var. *repens* (Schrenk) O. E. Shulz, lens-podded; and *Cardaria pubescens* (Meyer) Rollins var. *elongata* Rollins, globe-podded.

Hoary cresses are well represented in several Canadian herbaria, particularly in that of the Division of Botany and Plant Pathology at Ottawa, which contains the recent collections from the Federal-Provincial survey for perennial weeds. Study of this material discloses that heart-podded cress has been collected in all Canadian provinces, with the exception of Prince Edward Island, New Brunswick and Newfoundland. The other two cresses are known only from the three Prairie Provinces and British Columbia. Eastern infestations are obviously of one entity, although in the West lens-podded and globe-podded frequently occur together and more rarely infestations consist of heart-podded and lens-podded. At Lethbridge all three are found in the same area. In spite of earlier introduction, heart-podded is far less common in the West and appears to be less aggressive than the others in the group.

Consideration of this distributional pattern and reference to dates of collection suggest that the hoary cresses have entered Canada from two widely separated sources. The Eastern records for heart-podded date from 1878 and there are a number of collections prior to 1900. First records for Western Canada are: heart-podded, 1896; lens-podded, 1926; and globe-podded, 1928. The origin of the early introductions of heart-podded in both Eastern and Western Canada should be sought in Europe, where, according to Hegi (14), Bush (6), and Komarov (20), only this hoary cress occurs. All three hoary cresses are present in the Turkestan area and there is little doubt that impure seed of Turkestan alfalfa brought to this continent nearly 40 years ago is responsible for the later introductions of lens- and globe-podded (12, 23). Some part of the heart-podded—to judge by its occasional appearance with the other cresses in western infestations—is almost certainly of Turkestan origin.

In the Eastern provinces hoary cress does not constitute a serious problem. Only a few scattered patches occur in Manitoba and these are under control. The abundance and distribution of hoary cress in Saskatchewan are not completely known, but the 1949 Federal-Provincial weed surveys disclosed 386 acres of this weed on 13 quarter-sections in the North Battleford-Marsden area and 351 acres on 13 quarter-sections in the Regina-Broadview area (7). Alberta, with 825 quarter-sections infested, has by far the largest known extent of this weed in any Canadian province. Hoary cress is established in a number of areas in southeastern British Columbia, including the Okanagan Valley.

DISTRIBUTION IN ALBERTA

Table 1 lists the sites, habitats and control treatments of the infestations studied. Specimens from each site, with the exception of those

TABLE 1.—SUMMARY OF THE HOARY CRESS INFESTATIONS STUDIED IN ALBERTA

*Location near	Collection numbers	Species of hoary cress	Habitat	Special treatment, 1950
Lethbridge	3, 62	Globe	Irrigated grainfield	None
	4, 12, 60	Heart	Irrigated grainfield and roadside	2,4-D
	2, 12, 61	Lens	Farmyard and roadside	Chlorate
Coaldale	1, 45	Lens	Main street, ditch bank, with brome grass and other weeds	None
Tempest	11, 46	Globe	Grassy roadside and ditch bank	None
Taber	9, 47	Lens	Roadside ditch	Mowed
Wilson	8, 48	Lens	Road bank	2,4-D
Stirling	(No top growth)		Field margin	Chlorate
Raymond	5, 49	Globe	Pasture and beet field alkalied spot	2,4-D
		Lens ?	Roadside	Chlorate
	7, 50	Globe	Roadside, near Russian Knapweed	2,4-D
Woolford	28	Lens	Farmyard and grain field	2,4-D
Cardston	—	Lens	Field margin, near Russian Knapweed	2,4-D
Glenwood	23, 25, 57, 59	Lens	Irrigated grain field	2,4-D
	24, 58	Globe	Patches side by side	—
Hillspring	19, 55	Lens	Hay field, with Russian Knapweed	2,4-D
	22, 56	Globe	Grainfield	2,4-D
Pincher Creek	—	?	Grassy roadside	Chlorate
Cowley	16, 17, 21	Heart	Grainfield, roadside	2,4-D
	52, 53, 54	—	Ditchbanks, railroad right-of-way	2,4-D
Maunsell	14, 51	Heart	Roadside	2,4-D
Granum	30, 43	Globe	Grainfield, alkalied spot, originally garden site	2,4-D
Stavely	31, 44	Lens	Grainfield	2,4-D
			Farmyard	2,4-D
High River	—	Lens	Roadside	Chlorate
Dalroy	—	Lens	Grainfield	Patch cultivation
	32, 39	Lens	Roadside	2,4-D
	34, 40	Lens	Field crested wheat grass	Mowed
	33	Globe	Field crested wheat grass	2,4-D Mowed

* Location details filed with collections.

TABLE 1.—SUMMARY OF THE HOARY CRESS INFESTATIONS STUDIED IN ALBERTA—*Continued*

*Location near	Collection numbers	Species of hoary cress	Habitat	Special treatment, 1950
Kathryn	36, 42	Lens	Intermingled in grassy slough margin	None
	35, 41	Globe	Intermingled in grassy slough margin	2, 4-D 1948
Red Deer	38	Heart	Seeded pasture Kentucky Blue Grass	2,4-D
Camrose	Apparently eradicated	?	Grainfield	None Chlorate 1947-49
Daysland	63	Lens	Seeded pasture	None
Irma	66	Globe	Separate patches	None
	67	Lens	Same grainfield	—
Wainwright	65	Globe	Grainfield	None
	64	Lens ?	Summerfallow	Tillage
Tofield	68	Lens or Heart ?	Grainfield Farmyard	Chlorate —
Grande Prairie	69	Globe	Brome grass	2,4-D
	70	Lens	Field	—

* Location details filed with collections.

infestations treated with sodium chlorate before the surveyor's first visit, have been filed at Ottawa.

Total acreages involved are greatest east of Calgary and in the Lethbridge and Cardston areas. Elsewhere in the province the hoary cress infestations are light. All three cresses are represented in Alberta, but heart-podded is less widespread and abundant than the others. The infestations in the Cowley district and at Red Deer are exclusively heart-podded and this entity is also present in mixed infestations at Lethbridge. Lens- and globe-podded occur far more widely and range from near the southern border to the Grande Prairie area.

BIOLOGY OF THE HOARY CRESSES

These notes on the biology of the hoary cresses include field observations in Alberta, with some additional information gained from inquiry and the literature.

During the survey many farmers and others were questioned as to the date of earliest infestation and method of spread. In nearly all areas the hoary cresses are believed to have arrived about 25 or more years ago as impurities in legume seed, grass seed, or in hay and to have later been distributed by drainage-water, wind, farming and ranching operations in field and feed-lot. The present practice of shipping carloads of whole weed seeds for use in stock-feeding lots in various parts of the province also holds potential dangers in this regard.

In southern Alberta irrigation has aggravated the problem in respect to hoary cress and other weeds. In irrigated areas the establishment and spread of weeds are favoured by both the provision of abundant moisture for growth of seedlings and the transportation of seeds and root material washed from neglected ditch-banks. The movement of seed-infested soil with sugar-beets is thought to be of major significance in the periodic scattering of hoary cress along roadsides and near railway-sidings. Road-building and maintenance activities aggravate the problem. This combination of circumstances appears to result in a much larger proportion of new infestation originating from seed than occurs elsewhere in the province.

All three hoary cresses do well in the same habitats under a variety of soil conditions where moisture is in at least moderate supply. They are often abundant on alkali soil, globe-podded cress tending to show a preference for this condition. The fact that such soils are often wet late in the spring and proper cultural practice is delayed favours the persistence of hoary cress in this type of habitat. Although alkali conditions were present at some of the sites from which globe-podded cress was taken, e.g., near Raymond, Glenwood, and Granum, it seems clear that its distribution is not restricted to alkali areas (Table 1).

Much of the literature makes no distinction between the hoary cresses (3, 10, 32), but indicates that their root systems are very similar and extremely persistant. They possess a thick, corky layer in their bark, penetrate to a depth of 12 to 30 feet below the surface and have abundant food reserves (1, 24). Both the horizontal and vertical roots produce adventitious buds, which develop into rhizomes and shoots (10, 32).

In Alberta, hoary cress starts growth early in the spring, frequently blooming in May (1). Under California conditions (3), heart-podded cress is the earliest to complete blossoming and form seed (full bloom in late March, pods in April). There the lens-podded and globe-podded forms flower at the same time, but somewhat later than the heart-podded cress. In Alberta, however, the present survey revealed that in every location where globe-podded hoary cress appeared it was approximately 10 to 14 days later in flowering than either lens- or heart-podded cress. The latter two were in late flower and early pod stages during the last week in June, while globe-podded cress was still in early bud to flowering stage under comparable conditions in the Lethbridge, Stirling, and Calgary areas. The collections on file provide evidence in this regard. Apart from the purely botanical interest concerning times of flowering, such observations have a bearing on the scheduling of control practices, which will be discussed later.

As regards amount of seed set by the different cresses, there is reported to be considerable variation from year to year. Sexsmith (31) at the Lethbridge Experimental Station, has observed that, on the average, heart-podded produces more seed than the lens-podded and that in both plants there is considerable inter-colony variation in extent of sterility or seed abortion. The authors' observations concerning the infestations mentioned in Table 1 indicated that both forms were yielding large quantities of seeds during 1950, while globe-podded hoary cress was a very poor third. Heart- and lens-podded in adjacent patches at Lethbridge produced as many as

850 mature fruits per flowering stem. Nearly all the fruits on the heart-podded species contained two seeds. Lens-podded fruits had from two to four seeds, two or three being the most common.

Available information on the behaviour of the seeds of hoary cress indicates that they germinate promptly under normal growing conditions and that buried seed is not long-lived in the soil (1, 5, 21). Because of this behaviour the prevention of the establishment of new infestations from seed does not present so much of a problem as that caused by most weeds.

CONTROL AND ERADICATION OF HOARY CRESSES

Hoary cress, with its tough, deeply penetrating root system, numerous underground buds and large food reserves, possesses great powers of competition and endurance. A generally more weed-conscious public now appreciates more fully the need for effective systematic action against these persistent perennials. Alertness to recognize an infestation in its early stages and to take prompt action can result in large savings in time and money.

The control and eradication methods most commonly in use or recommended employ:

(*a*) Sodium chlorate
(*b*) Intensive cultivation
(*c*) Alternating tillage and grain-cropping program, including use of a selective herbicide in the crop
(*d*) Grassing, accompanied by use of a selective herbicide.

(*a*) *Sodium Chlorate*

Sodium chlorate and "Atlacide" are in wide use for attempted eradication of small patches of hoary cress and other perennial weeds. Several municipalities depend almost entirely upon chlorate treatments for this purpose. Active weed inspectors or field supervisors are in charge (33). In the Stirling-Raymond area it is common practice to use six to eight pounds of chlorate per square rod for the first application at flowering-time of the cress. A second treatment during the same year is sometimes advisable to kill resprouts, which may appear within the treated area or from roots extending beyond the borders of this area. It is, of course, recommended that the original treatment be applied to include ground several feet on all sides of the patch in order to minimize the amount of regrowth from the spreading root-system. Additional treatments one, two, or three years after the first treatment may be necessary.

In the Highwood Municipal District (High River) sodium chlorate applied by a municipally controlled truck-mounted sprayer has been used extensively in efforts to eradicate hoary cress. When regrowth occurs it is taken care of by means of a hand-sprayer. Costs of spraying cress on road-allowances are born by the municipal district or by the farmer when the weed is on his property.

In the Camrose, Tofield and Wainwright regions, where hoary cress infestations are relatively few and small, most patches under vigilance of municipal authorities have been subjected to repeated sodium chlorate treatments with obviously good results. One farm visited near Daysland,

however, provides an example of an exception to the above statement. There a farmer's early efforts at soil sterilization, dating back eight or ten years, were ineffective and the infestation spread over about thirty acres. Within recent years this hoary cress has been partially held in check by brome grass sod, a practice to be discussed later.

A number of factors appear to affect the results obtained with sodium chlorate. No doubt timing of application of the chemical has considerable bearing on the success or failure of the treatments. At Lethbridge, Sexsmith (31) favours September or later applications of chlorate to the soil alone rather than to the soil weed foliage together. Re-treatments in midsummer of subsequent seasons are usually necessary. Reports from elsewhere indicate that under some conditions, at least, most effective results can be obtained by a light, followed by a heavy, application of chlorate, e.g., a 1-lb. initial application succeeded by a 4- or 5-lb. dosage per square rod made at 10-day intervals during the blooming stage of the cress. Late fall, single treatments of 6 lb. per square rod, also were credited with complete eradication of the weed in Idaho (17).

There is evidence that under some soil conditions plant response to sodium chlorate may be quite variable and unsatisfactory (1). Plant variation and history of treatments play a part in this respect and there is some evidence that inter-specific variations in susceptibility exist among the hoary cresses. Preliminary work at the Federal Experiment Station at Genesee, Idaho, indicates that the three hoary cresses differ in resistance to sodium chlorate (19): globe-podded required about 2 lb. per square rod; heart-podded, 5, and lens-podded, 9. This point would warrant further investigation.

Other treatments, such as hoeing, carbon bisulphide, fire, or application of oils (29), are useful in combating hoary cress in small patches but their use, like that of sodium chlorate, becomes too expensive and impractical when dealing with extensive field infestations. Flooding is another method that can be used with success in certain cases where the soil is heavy enough to hold water without excessive seepage (29).

(*b*) *Intensive Cultivation*

According to Pavlychenko (24, 25) and others, the roots of hoary cress may resist successfully a complete inhibition of their top growth for a period of one season without noticeable loss in vigour. In the second consecutive year of this treatment they suffer noticeably, but often preserve some of their vitality even after three years.

Pemberton's survey in Australia (26) shows that hoary cress plants must be cut off at depths greater than 18 inches below soil surface in order to prevent regeneration from underground stems. The aim in eradication by tillage must be continuous starvation of the root material for at least two years. In general, this means up to 25 or more cultivations at relatively short intervals none of which must be long enough to permit more than a few days' regrowth. Barr's researches on root-food reserves have a bearing on this point (2). The proper implements should be used (13) and, if it is at all practical, each patch should be dealt with as an isolated unit. Probably the most common means of spreading hoary cress in agricultural lands is the dragging of root material by tillage machinery

moving through localized patches of the weed to other parts of the field. Several examples of the consequence of such malpractice are visible in the hoary cress areas of southern Alberta.

Sexsmith (30), whose main experiments on hoary cress are in progress in the Dalroy area east of Calgary, reports that tillage operations should be begun early in the season. Postponement until near flowering-time, although often recommended in dealing with less persistent perennials, such as Canada Thistle and Sow Thistle, may result in more than a year's delay in the eradication of hoary cress.

Undoubtedly a number of the reported failures of attempts at cultural control under practical farm conditions can be attributed to improper timing of the tillage operations. Pressure of other farm work, particularly at harvest-time, or disturbances of tillage schedule by inclement weather conditions, often appear to be responsible for the failure or prolongation of the battle with hoary cress.

(*c*) *Alternating Tillage and Grain-cropping Program, Including Use of a Selective Herbicide in the Crop*

At best, black or green summerfallowing of large areas is costly, and, especially where land is subject to erosion, an alternating cultivation and grain cropping plan is more feasible. In such a program cultivation during the crop year should be commenced immediately after the crop is taken off and continued until freeze-up (8). Five years or more may be required for complete eradication of hoary cress if a grain crop is taken off every other year.

Under irrigation conditions in the Lethbridge area one year's summerfallow, followed by two years of intertilled crops, such as sugar-beets, often fail in the eradication of hoary cress. More prolonged intensive cultivation appears to be necessary but is sometimes embarked upon grudgingly, if at all.

Control of hoary cress in growing grain crops by the use of 2,4-D as a supplement to good tillage and cropping practice is being tried with enthusiasm by a number of progressive farmers in the worst cress-infested areas of the province. Although it is probably too much to expect that, where grain crops are grown year after year, single annual treatments with 2,4-D will within a short period of years eradicate the associated hoary cress, it is encouraging to find that the Agricultural Service Board for the Pincher Creek-Cowley area reports satisfactory control of heart-podded cress in cropped fields treated for three consecutive years with 5 or 6 oz. 2,4-D acid equivalent per acre (ester formulation).

The above mentioned 2,4-D treatment stunts the cress plants, appreciably reduces their competitive ability, and is almost completely effective in preventing their seed production. The few seeds that do form on some of the plants are not viable, according to some reports, but this point should perhaps receive additional investigation. At Cowley the same relatively low rate of 2,4-D application (5 oz. per acre) is used for control of roadside infestations of heart-podded hoary cress. The response to the chemical is similar to that observed in grain fields and the question arises as to whether higher rates of application might be more effective for this work.

In order to get some preliminary information on this question, one of the authors* laid down simple experiments at Cowley, Hillspring, and Lethbridge involving plots treated with 8, 16, 32 and 64 oz. 2,4-D acid equivalent during the last week in June, when field spraying was general in these areas. The tests included heart-podded cress at Cowley, the lens-podded variety at Hillspring, and heart- and lens-podded cress at Lethbridge. At each location the observations a month later showed that 8-oz. acid equivalent permitted pod formation but completely prevented seed production. Essentially the same results occurred from the 16- and 32-oz. applications, except that the higher rates caused somewhat more leaf and stem burning. The 64-oz. rate, however, prevented pod development and almost completely desiccated top growth. No regrowth had appeared in any of the plots observed at this time, but examination of root material indicated that only limited damage had occurred below the surface of the ground. Additional observations in another year of course would be necessary to determine whether the various treatments produced appreciable differences in root survival. These limited tests suggest, however, that one-half pound 2,4-D acid equivalent (near the upper safe limit for use in grain crops) is necessary to prevent seed production completely and that further experimentation is needed to determine the relative values of returns in proportion to costs of the heavier applications on non-cropped land.

With the exception of the practice noted at Cowley, weed control officials and farmers have generally used 12 oz. to one pound or more acid equivalent of 2,4-D per acre for treatment of patches of hoary cress on roadsides or in grain fields. Experience over the next few years should reveal the optimum rates of application of 2,4-D for this work. Ester formulations have so far been used almost exclusively, but some officials, notably in the Calgary district, expressed the view that amine formulations, although slower-acting, are under some conditions more deeply penetrating and hence sometimes more effective than esters used on hoary cress. This is another problem that appears worthy of further research.

In England, Blackman and Holly (4) found that statements about the differences between allied compounds when applied to hoary cress can be precise only if comparisons have been made at various stages of the growth cycle. Their work showed that if MCPA (2 methyl 4 chlorophenoxyacetic acid) is used, the cress should be sprayed when flower-buds are forming, whereas with DCPA (2,4-D) spraying should not take place until the hoary cress is in flower. Two successive yearly sprayings gave almost complete eradication of the weed, but Blackman and Holly point out that provision should be made for the spring sowing of a third crop resistant to growth regulating herbicides. This spring sowing follows two autumn-sown crops in the program mentioned.

(d) Grassing Accompanied by the Use of a Selective Herbicide

Where eradication of hoary cresses is being attempted in conjunction with the growing of a crop and the conservation of the soil, the most promising method appears to be a combination of grass competition with the application of 2,4-D. Grass alone is not enough (9, 29).

*W. G. Corns.

At Daysland, Red Deer and Cowley, for examples of infestations in various parts of the province, one or two years' summerfallow, followed by three to four years of brome grass or crested wheat grass, diminish considerably the density and vigour of the above-ground population of hoary cress, but it is not uncommon to find a heavy growth of the weed appearing during the year that the sod is broken. Apparently very little surface growth is necessary to maintain the vitality of the root system.

There is evidence that where 2,4-D is adequately used in conjunction with the grassing program, hoary cress can usually be eradicated within a reasonably short period of years. At Red Deer, land infested with heart-podded hoary cress was placed under municipal control seven years ago. It was summerfallowed for two consecutive years, then divided into strips and seeded to pure stands or to mixtures, including brome grass, crested wheat grass, creeping red fescue, and Kentucky blue grass. During the last three years the various strips have been sprayed with 2,4-D ester applied to flowering plants at $\frac{1}{2}$ to $1\frac{1}{2}$ lb. acid equivalent per acre. The areas predominantly in Kentucky blue grass are now practically free from hoary cress. It is planned, however, to not break up the sod for another year or two at least, during which time chemical treatments will be applied in mid-summer to surviving weeds. Most of the hoary cress plants observed on this land would, most probably, have failed to produce flowers this year, even had 2,4-D treatments been omitted.

In the Grande Prairie area, recommended practice for eradication of globe- and lens-podded hoary cress involves seeding to brome grass at 10 to 12 pounds per acre or to creeping red fescue at 8 to 10 pounds per acre. Application of 2,4-D ester at 16-oz. acid equivalent per acre is made when the cress is well budded, and resprouts, if any, are sprayed again in September. The following year one application of 2,4-D is usually sufficient, followed by spot treatments the next year. Such a program, begun four years ago on heavily infested land at Beaverlodge, has eliminated the hoary cress in some of the treated areas. Determination of the period required for the general success of this method awaits results, that is to say, after the land is broken at different lengths of time after the top-growth of the cress has disappeared. The land is useful for hay or pasture during the grassing period and is brought to a state of maximum clean crop productivity by the use of this method.

The choice of the most highly competitive grass naturally varies with the climatic and soil conditions. In general, in southern Alberta brome grass is best where moisture is not too limiting. Crested wheat grass is recommended for drier areas and for arid ridges, etc., in otherwise moist areas. The use of creeping red fescue and Kentucky blue grass has already been noted as giving good results in the central and northern parts of the province. Helpful assistance in the selection of the grasses best adapted to local conditions can, of course, be obtained by consultation with the District Agriculturist, Field Supervisor, or Experimental Station officials, where such services are available.

SUMMARY

1. More than 800 quarter-sections of land in Alberta are infested with three hoary cresses—*Cardaria draba* (heart-podded), *Cardaria draba* var. *repens* (lens-podded) and *Cardaria pubescens* var. *elongata* (globe-podded).

2. A number of typical habitats were studied and collections taken. The three hoary cresses do well in various situations, regardless of soil type, where moisture is in at least moderate supply. They sometimes grow in adjacent patches or intermingled in the same patch. Globe-podded cress tends to show a preference for alkali conditions.

3. Total acreages involved are greatest east of Calgary, and in the Lethbridge and Cardston areas. Elsewhere in the province the hoary cress infestations are light.

4. Heart-podded is much less abundant and widespread than the other two hoary cresses. Pure stands of heart-podded occur about Cowley and at Red Deer, and this plant is associated with the other species at Lethbridge. The many other stands are of either lens- or globe-podded or both.

5. The persistence and spread of existing infestations appears to be mainly attributable to vegetative reproduction. In irrigated areas conditions are more favourable than elsewhere for the establishment of new infestations from seed. Because of the short life-span and ready germination of hoary cress seeds they do not cause major difficulty under good farming practice.

6. During 1950 globe-podded was one to two weeks later in flowering than either lens- or heart-podded hoary cresses. The latter two were both in the advanced flowering-stage late in June. Time of flowering appears to be an important consideration in relation to choice of best time for application of herbicides.

7. Systematic, though various, methods are being used to control or eradicate the hoary cresses in Alberta. The enthusiastic efforts of weed control officials supported by the farmers are playing a major part in the campaign. The methods involve soil sterilization, intensive cultivation, alternating tillage and grain cropping supplemented by applications of 2,4-D, and grassing accompanied by 2,4-D treatment. The latter combination appears to hold most promise for eradication of hoary cresses in large acreages while at the same time providing for hay or pasture returns and assistance in soil conservation.

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SUPPLEMENTATION OF ALFALFA AND MARSH HAYS WITH LINSEED, RAPESEED AND MUSTARDSEED OIL MEALS IN GESTATION RATIONS FOR EWES

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It is generally recognized that legume forages contain more calcium, protein and vitamin A (carotene) than do non-legume forages, and they have been shown to be superior in pregnant-ewe rations by Shrewbury *et al.* (8) and by Williams *et al.* (11). The latter investigators found little benefit resulted from the administration of supplementary vitamin A to ewes receiving any one of several non-legume forages fed with complete mineral supplements.

The need for good fleshing in ewes during late gestation has been emphasized by the works of Hammond (6), Thompson and Fraser (9) and Wallace (10), and since the differences in the Total Digestible Nutrient (TDN) values of forages varying widely in quality are proportionately smaller than the Digestible Protein (DCP) differences attention was focused on the need for supplementary protein with non-legume roughages. Favourable effects due to the addition of protein to low-protein hays were observed by Bell *et al.* (2) and by Burroughs *et al.* (4).

This investigation concerns the use of rapeseed oilmeal and mustardseed oilmeal in comparison with linseed oil meal as supplements to roughages for wintering pregnant ewes under practical conditions. The oilmeals of rape and mustardseed became available for livestock feeding during World War II but it was known that rapeseed oilmeal contained a toxic principle (1-5-vinyl thiooxazolidone, 1) and was somewhat unpalatable to livestock. Investigations conducted with turkeys have shown severe thyroid enlargements to result from the feeding of levels of rapeseed oilmeal sufficient to meet the protein needs in practical grain rations (Blakely and Anderson, 3). Burkitt (5) has recently reported on the digestibility of rapeseed oilmeal for sheep and mentioned its unpalatable nature. Little was known, however, of the value of mustardseed oilmeal but in belonging to the same genus (*Brassica*) as rapeseed oilmeal it was suspected of similar shortcomings. It would seem important to know more about the limitations of these products as protein supplements for live stock.

EXPERIMENTAL

Immediately following the 1948 breeding season, the University ewe flock was divided into eight groups, each equally represented by Hampshire, Rambouillet and cross-bred ewes of range type. They were housed in open sheds, fed their respective roughages ad libitum outdoors in feed-racks, and watered daily.

Groups 1 to 4, inclusive, were fed alfalfa hay of about average quality whereas groups 5 to 8 received marsh or lowland hay (dominantly *Carex* species). In later studies involving similar hays alfalfa was found to

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TABLE 1.—INITIAL WEIGHTS, WEIGHT LOSSES TO PARTURITION AND LAMBING PERCENTAGES OF EWES FED ALFALFA OR MARSH HAY WITH VARIOUS PROTEIN SUPPLEMENTS

Lot No.	Ration fed	Number of ewes		Average initial weight of ewes lambed	Average weight loss to lambing	Lambing percentage[1]
		On test	Lambed			
				lb.	lb.	
1	Alfalfa hay	22	21	133	9.6 ± 2.0[2]	162
2	Alfalfa + linseed oilmeal	22	22	130	5.8 ± 1.7	159
3	Alfalfa + mustardseed oilmeal	22	21	137	4.0 ± 2.7	148
4	Alfalfa + rapeseed oilmeal	22	22	135	6.5 ± 1.9	136
5	Marsh hay	22	20	136	27.1 ± 2.8	132
6	Marsh hay + linseed oilmeal	23	21	139	17.1 ± 2.3	126
7	Marsh hay + mustardseed oilmeal	22	22	136	15.0 ± 2.3	143
8	Marsh hay + rapeseed oilmeal	22	20	136	14.7 ± 2.3	133

[1] Lambing percentage based on number of ewes which lambed.
[2] Standard errors of the means.

contain 15 per cent DCP and 64 per cent TDN and the corresponding values for marsh hay were 2.5 and 54 per cent.

Protein supplements were allowed in shallow troughs in quantities sufficient to supply an average of one-half pound of the oilmeal per head daily. Groups 1 and 5 served as controls and received no supplementary protein. Groups 2 and 6 were given linseed oilmeal; 3 and 7 mustardseed oilmeal, and 4 and 8 rapeseed oilmeal.

All ewes had continuous access to a mineral mixture having the following composition: bone meal, 50 pounds; salt, 50 pounds; cobalt sulphate, 0.8 ounce; manganese sulphate, 0.5 ounce; copper sulphate, 0.3 ounce; ferrous sulphate, 4.0 ounces, and stabilized potassium iodide, 2.4 ounces.

The ewes were maintained on their respective experimental rations until the commencement of the lambing season on April 1. Individual weights were taken at the time of allotment (January 13), on April 1, and again following parturition. Data on the new-born lambs included sex, birth weight, number born and a grading of vigour or quality according to the system employed by Williams *et al.* (11), and reproduced here:

(*a*) *Good*—Lambs of good weight, strong and which appear to have excellent chances of survival. Lambs in this category do not require any assistance at nursing.

(*b*) *Fair*—Lambs of good weight and fairly strong. These lambs should appear to have a good chance of survival. They may exhibit a little softness or sleepiness as opposed to brightness or life. They may require assistance at nursing for the first day.

(*c*) *Weak*—Soft, weak or small lambs. These lambs may require assistance at nursing for a considerable period or may need extra heat and bottle feeding. Their chances of survival would appear to be negligible without the extra assistance. Whenever possible, the cause of this grading was recorded.

(*d*) *Dead*—All lambs born dead or which die within a few hours of birth from causes other than accident.

All defects and any evidences of abnormality or disease in the lambs or ewes were recorded.

RESULTS AND DISCUSSION

It was observed throughout the experiment that ewes consumed rapeseed oilmeal and mustardseed oilmeal less readily than linseed oilmeal but in no instance did they fail to eventually eat their allotments during the day. It is recognized that such a test is severe and may not indicate too well the palatability of concentrate mixtures containing these oilmeals.

The addition of protein supplements to alfalfa rations for breeding ewes in advanced pregnancy might be expected to influence lambing performance if additional energy (TDN) is required but protein per se would appear to be unnecessary (7). Marsh hay, being inferior in both DCP and TDN contents, might be expected to respond to both energy and protein additions. This proved to be the case for it is evident in Table 1 that the addition of one-half pound of protein supplement per head daily resulted in smaller weight losses in ewes during pregnancy. More marked improvement occurred in groups fed marsh hay but in no case did the addition of protein (and mineral) supplements sufficiently improve the response to equal that of the group receiving alfalfa alone. In making this comparison it should be borne in mind that the slightly higher lambing percentage in lot 1 (alfalfa) as compared to those which received marsh hay might indicate that relatively more of the weight loss during gestation

TABLE 2.—BIRTH WEIGHTS, CONDITION AT BIRTH AND MORTALITY OF LAMBS TO DOCKING AGE

Ration fed to ewes	Birth weights of lambs			Birth grades of lambs				Mortality to docking age
	Singles	Twins	Average	Good	Fair	Weak	Dead	
	— Pounds —			— Number of lambs —				
Alfalfa hay	11.8 ± 0.5	8.6 ± 0.3	9.4	31	2	1	0	4
Alfalfa hay + linseed oilmeal	10.1 ± 0.4	9.2 ± 0.2	9.4	33	1	0	1	1
Alfalfa hay + mustardseed oilmeal	11.0 ± 0.5	8.1 ± 0.4	9.0	28	1	1	1	7
Alfalfa hay + rapeseed oilmeal	9.7 ± 0.5	8.8 ± 0.2	9.2	29	0	0	1	2
Marsh hay	10.5 ± 0.4	6.6 ± 0.6	8.5	17	3	5	4	6
Marsh hay + linseed oilmeal	10.7 ± 0.5	7.3 ± 0.5	8.8	23	3	2	1	4
Marsh hay + mustardseed oilmeal	10.3 ± 0.6	8.0 ± 0.4	8.9	23	3	0	0	1
Marsh hay + rapeseed oilmeal	10.7 ± 0.5	8.1 ± 0.4	8.9	24	5	0	0	4

was due to carrying more lambs, and furthermore, that the weight losses in marsh hay-fed groups (lot 5 in particular) would undoubtedly have been larger if the ewes had been fed their test rations until they had lambed.

The size and vitality of lambs at birth (Table 2) rated highest in groups fed alfalfa. The addition of protein supplements to alfalfa had little or no effect on birth weights and grades but some improvement may have resulted in lambs dropped by ewes fed marsh hay when supplemented. This is particularly in evidence in twin lambs since the average weight of twin lambs was 6.6 pounds when no protein was added, and was from 0.7 to 1.5 pounds heavier when a protein supplement was included in the gestation ration. Again it is likely that lambing performance reflected to some extent the improved feeding during late pregnancy in the groups fed marsh hay.

The reason for protein-mineral supplemented marsh hay being inferior as a ration to alfalfa is not clear from this study but it could be accounted for in part at least in terms of palatability because if the ewes consumed 3.8-4.0 pound of marsh hay (54 per cent TDN, 2.5 per cent DCP), along with 0.5 pound of oilmeal, they should have received the necessary TDN and DCP (7). It is extremely doubtful, however, that roughage consumption in marsh hay groups equalled that in groups fed alfalfa, hence the plane of nutrition in general probably remained in favour of alfalfa despite attempts to overcome protein, mineral and energy deficiencies.

It is of interest in comparing the protein supplements to note that despite a degree of unpalatability in rapeseed and mustardseed oilmeals, they served as well as linseed oilmeal in maintaining gestation weights in ewes and in improving the weight and vitality of lambs at birth. Contrary to the studies of Blakely and Anderson (3) with turkey poults no cases of thyroid enlargement were noted by gross examination of the ewes or lambs from lots receiving rapeseed oilmeal supplements. Hence it would appear that mustardseed oilmeal and rapeseed oilmeal are acceptable protein supplements for pregnant ewes and possibly for other ruminants although palatability may present a problem where heavy and rapid consumption of concentrates is desired.

SUMMARY

Eight groups of 22 or 23 ewes were allotted at the close of the breeding season to either alfalfa hay or marsh hay rations supplemented with minerals and with (*a*) nil, (*b*) linseed oilmeal, (*c*) rapeseed oilmeal, or (*d*) mustardseed oilmeal for a period of $2\frac{1}{2}$ months. Ewes receiving alfalfa alone were heavier at the post-partum weighing and produced slightly better lambs than did those receiving marsh hay even with added protein and mineral supplements.

The use of supplementary protein improved post-partum weights in all groups and improved the quality of lambs, twins in particular, from ewes fed marsh hay. Rapeseed oilmeal and mustardseed oilmeal compared favourably with linseed oilmeal except in palatability. No thyroid enlargements were noted by gross examination.

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THE EFFECT OF RUMINANT DIGESTION ON FORAGE LIGNIN[1]

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INTRODUCTION

The estimation of pasture forage digestibility by freely grazing animals has an important bearing on the determination of the nutritive value of pastures. Unfortunately no completely satisfactory and reliable method has been developed for this purpose. One of the best now available utilizes the relatively indigestible substance lignin, as a natural reference indicator, the ratio of forage lignin to feces lignin being used to obtain digestibility coefficients (7). Some of the disadvantages of this method are that it is sometimes subject to marked and unexplainable variations (8) and furthermore the 72 per cent sulphuric acid lignin determination is an empirical one which is open to criticism.

The chemical changes which lignin undergoes in the digestive tract of herbivorous animals are not too well understood but are of interest both from the point of view of digestibility studies and from the aspect of fundamental lignin chemistry. It is usually conceded that lignin is relatively indigestible and it might be supposed that it would appear in the feces in a comparatively unaltered condition. Bondi and Meyer (2, 3) however, have obtained evidence that very profound changes occur in the lignin molecule under these conditions, the most notable being the non-production of vanillin from isolated fecal lignin when oxidised with alkaline nitrobenzene. Another notable feature of their work is the failure to obtain syringaldehyde from the oxidation of the forages, these consisting of several Gramineae and several Leguminosae. This latter claim is remarkable in view of the good yields of syringaldehyde obtained from several members of the Gramineae by Hibbert *et al.* (4) and from wheat plants at various stages of maturity by Stone *et al.* (10). Indeed so reliable is the production of these aldehydes from various plant materials that Hibbert *et al.* (5) have suggested that they be used as a method of taxonomic classification.

In order to investigate these points, and to explore the possibility of utilizing the aldehydic degradation products of lignin as index substances for digestibility studies, an alkaline nitrobenzene oxidation was carried out on a number of forages and their corresponding sheep feces.

EXPERIMENTAL

Four cured hays consisting of two grasses, one legume and one other dicotyledonous non-legume, were selected for study. They were Crested Wheatgrass, *Agropyron cristatum* (L.) Beauv. at the flower stage; Smooth Brome Grass, *Bromus inermis* Leyss. at the mature but still leafy stage; Alfalfa, *Medicago sativa* L. at the early to medium flower stage; and Burning Bush, *Kochia childsii* Hort at the flower stage.

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The treatment which these forages had received prior to analysis was as follows:

The brome straw was permitted to dry in the field. The other forages were removed from the field while green and dried in a forage dryer at approximately 38° C. Samples were prepared for analysis by grinding in a hammer-mill to pass a one-half millimeter screen.

Air-dried fecal samples corresponding to the above feeds were obtained from sheep on conventional digestibility trials. In all cases a 5-day preliminary period had been observed before quantitative collections were started and during the trials the sheep were maintained on the pure species of plant in every case.

Feces pellets were prepared for analysis by powdering in an Osterizer until they approached a degree of fineness comparable to that of the feed.

Nitrobenzene oxidations of feed and fecal samples and quantitative estimations of the aldehydes were carried out on the air-dried material by a method described elsewhere (9). Moisture and ash were determined on separate samples and the appropriate corrections applied to give the aldehyde yield and lignin content on an ash- and moisture-free basis.

Lignin determinations were carried out by a modification of the 72 per cent sulphuric acid procedure of Ellis *et al.* (6). The modification included hydrolysis with 5 per cent sulphuric acid before enzymatic digestion and substitution of the pepsin-HCl digestion mixture by a trypsin-Na_2CO_3 solution. According to Armitage *et al.* (1), this modification yields a lignin with a lower nitrogen content from a plant material of high protein content.

RESULTS AND DISCUSSION

There is evidence that the p-hydroxybenzaldehyde, which appears as one of the oxidation products of certain plants, is not derived from lignin. Its origin is believed to be the tyrosine present in plant protein (10). In view of this, and because of the irregularity of the p-hydroxybenzaldehyde yields found in this work, the only aldehydes which will be considered in the discussion of results are vanillin and syringaldehyde.

It is difficult to reconcile the results obtained by Bondi and Meyer (2) with the data presented in Table 1. In contrast to these workers, good yields of syringaldehyde were obtained from the oxidation of all samples of forage, as would be expected with angiosperms. Furthermore, good yields of vanillin and syringaldehyde were obtained from all samples of feces in marked contrast to the above workers who could detect no trace of any aldehyde following the oxidation of fecal material. Admittedly, Bondi and Meyer (2) oxidized the lignin isolated from the feces, whereas in this study the feces were oxidized directly; but it is unlikely that the isolation would so markedly affect the structure of the lignin as to reduce the aldehyde-yielding property to zero.

Bondi and Meyer found that the lignins which they isolated from feed and from feces had the same methoxyl and nitrogen contents and the same solubility properties. The fecal lignin gave rise to vanillic acid by suitable degradation, showing that the guaiacyl nucleus had remained intact. They therefore attributed the non-production of vanillin by nitrobenezene oxidation of fecal lignin to the absence of an unsaturated side chain in the

TABLE 1.—PERCENTAGE ALDEHYDE YIELD FROM NITROBENZENE OXIDATION

	Dicotyledons						Monocotyledons					
	Kochia			Alfalfa			Crested wheatgrass			Bromegrass		
	Forage	Feces*		Forage	Feces*		Forage	Feces*		Forage	Feces*	
		A	B		A	B		A	B		A	B
Vanillin	0.73	1.40	1.55	0.73	2.18	2.22	1.37	2.31	3.71	0.86	1.61	2.08
Syringaldehyde	0.23	0.52	0.49	0.47	1.19	1.44	1.14	1.99	3.09	0.72	1.40	1.74
p-Hydroxybenzaldehyde	0.14	0.10	0.30	0.25	0.33	0.76	0.21	0.32	0.57	0.15	0.18	0.36

* Column A represents the experimental values obtained, based on ash-free feces.
Column B represents the theoretical yield of aldehydes calculated from the digestibility coefficients given in Table 2, row 4, i.e.,

$$B = \frac{\text{organic matter in forage}}{\text{organic matter in feces}} \times \text{aldehyde yield from forage}$$

lignin molecule. The results presented here do not support this contention. This can be seen by comparing columns A and B of Table 1. Column A gives the yields of vanillin and syringaldehyde actually obtained by oxidizing the feces; B gives the yields calculated from the forage values and the percentage of organic matter digested. If the lignin were completely unaltered in amount and structure by passage through the animal, columns A and B should be identical and the vanillin yield from feces could then be used as a measure of digestibility.

In the case of the two dicotyledons studied the actual and calculated yields of aldehyde are quite similar with the exception of syringaldehyde from alfalfa. This may be taken to mean that there is very little degradation of the lignin molecule in the digestive tract of the animal. A conventional lignin determination performed on the feed and feces should confirm this, and Table 2 shows that the lignin in the feces of sheep fed on dicotyledons is a little higher than would be predicted from the forage lignin and digestibility factor. This higher value can be explained by the fact that the method of determining lignin used here is not completely reliable. In particular, the presence of protein will give high results due to the formation of humic acid under the action of 72 per cent sulphuric acid and some such contaminant as humic acid must have been present in the fecal lignin.

In the case of the monocotyledons, the aldehyde values given in columns A and B of Table 1 do not correspond, the actual yield being lower than the calculated figure. This indicates that the lignin molecule of the monocotyledon has been degraded in the animal. There are two ways in which this degradation might have occurred: (i) part of the lignin could have been completely digested by the animal; (ii) the grouping in the lignin molecule which is susceptible to cleavage by alkaline nitrobenzene could have been modified, but without solubilization of the lignin. Either would give a reduced yield of aldehyde. In the first case a conventional lignin determination would show a lower lignin content in the feces than the digestibility factor would predict, while in the second case the percentage of lignin found in the feces would be the same as the calculated percentage. Table 2 shows that the first of these two alternatives is the most probable. The amount of lignin found in the feces of sheep fed on monocotyledons

TABLE 2.—LIGNIN AND DIGESTIBILITY DATA

		Dicotyledons		Monocotyledons	
		Kochia	Alfalfa	Crested wheat-grass	Brome-grass
Lignin, per cent	Forage	9.0	6.5	8.0	9.7
	Feces	23.4	24.8	20.9	19.9
	Feces (calculated)[1]	19.1	20.0	21.7	23.5
Digestibility, per cent (organic matter)	From feeding trials[2]	53	67	63	59
	From lignin values	62	74	62	51
	From vanillin yield	48	66	41	47

[1] $\frac{\text{Organic matter in forage}}{\text{Organic matter in feces}} \times$ lignin (72% H_2SO_4) in forage.

[2] Data supplied by J. M. Bell, Dept. of Animal Husbandry, University of Saskatchewan, Saskatoon, Sask.

was less than the value calculated from the digestibility factor assuming no lignin decomposition.

Taken together, it is believed that the data presented in Tables 1 and 2 show that the two dicotyledon lignins were not digested by the animal or modified to any appreciable degree, and that the two monocotyledon lignins were partially digested, the undigested portion remaining unmodified.

A possible explanation for the difference between the two groups of lignins may be found in the much higher percentage of aldehydes obtainable from the monocotyledon forages than from the dicotyledons. The lignin contents are of the same order, but the vanillin and syringaldehyde yields are quite different. It is possible that those lignins which are most susceptible to nitrobenzene oxidation are also those most readily attacked by the digestive system of sheep, and for the same reason—that is, because of the presence of many easily oxidizable bonds in the lignin molecule.

These results were obtained from insufficient samples to make generalizations concerning the digestion of forage lignins, but the trends observed seem sufficiently interesting to warrant further study of other monocotyledon and dicotyledon forages.

SUMMARY

Vanillin and syringaldehyde were obtained in good yield from the feces of sheep which had been fed on a number of common forages. When studied in conjunction with lignin determinations the aldehyde yields were interpreted as follows: In the case of dicotyledonous forages the lignin was relatively unchanged by passage through the animal whereas the monocotyledon lignins were partially digested.

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THE DISCOVERY OF NEMATODES BELONGING TO THE GENUS HETERODERA IN BRITISH COLUMBIA AND THEIR HOST RELATIONSHIPS[1]

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Nematodes belonging to the genus *Heterodera* Schmidt, 1871, were recently discovered in widely separated points in the coastal regions of British Columbia, first on vetch and some other legumes in a nursery close to Victoria, and later on peas at Ladner in the Fraser Valley. This discovery is of special interest, first, because no species of the genus had previously been found in British Columbia, and, second, because after the discovery an embargo was placed on shipments of nursery stock from British Columbia to the United States. This embargo was subsequently removed. All earlier reports relating to this genus in British Columbia referred to the root-knot nematode, *Heterodera marioni*, which in recent years was placed in the genus *Meloidogyne*.

A survey of the infestation near Victoria was conducted on June 8, 1951, with the co-operation of nematode specialists from the United States. This survey included the examination of soil samples taken from different sites in the nursery, and the collection and examination of plants found growing in these sites. The soil samples disclosed the presence of cysts in both cultivated and wild virgin areas of the nursery property, a fact which suggested that the nematode might be indigenous and of wider distribution in the Pacific Northwest. This was subsequently confirmed by a survey in western Washington by United States officials, which established the presence of a species of *Heterodera* on legumes there also. A wide range of species and varieties of plants were examined in the nursery near Victoria, but infection was found on only a single specimen of vetch, *Vicia* sp., in the original survey. Special attention was given to oats, as the nematode was at first suspected to be *H. avenae*, the oat nematode; but no member of the *Gramineae* was found infected. Subsequently, on June 26, another collection of plants was made at the nursery, and through it the host range of the nematode was extended to include also *Trifolium dubium* Sibth., *T. pratense* L., *T. repens* L., and *Phaseolus vulgaris* L., of the *Leguminosae*, and *Capsella bursa pastoris* (L.) Medic. and *Erodium cicutarium* (L.) L'Her. These infected plants, together with infected pea roots, which had just then been received from H. N. W. Toms, of the Dominion Laboratory of Plant Pathology, Vancouver, B.C., were forwarded to the Division of Nematology, United States Department of Agriculture, for examination. Mr. Toms reported that on June 29 he examined a number of patches of dwarfed, yellow, or wilting plants in a 5-acre field of peas at Ladner. Finding nematodes present on them, he submitted infected material to A. D. Baker, Division of Entomology, Science Service, Department of Agriculture, Ottawa, and was informed that the species of *Heterodera* present was probably H. *göttingiana* Liebscher, 1892.

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The report from the Division of Nematology, U.S.D.A., is summarized in Table 1.

TABLE 1.—NEMATODES FOUND IN NATURALLY-INFECTED PLANT MATERIAL FROM VICTORIA AND LADNER, BRITISH COLUMBIA

Location—Host	Nematode	Forms present in collections		
		Females	Eggs	Larvae
Victoria—*Trifolium pratense*	*Heterodera* sp.	+	+	+
Victoria—*Trifolium repens*	*Heterodera* sp.	+	+	−
Victoria—*Trifolium dubium*	*Heterodera* sp.	+	+	−
Victoria—*Phaseolus vulgaris*	*Heterodera* sp.	+	+	+
Victoria—*Erodium cicutarium*	*Heterodera* sp.	+	+	−
Victoria—*Capsella bursa-pastoris*	*Heterodera* sp.	+	−	−
Ladner—*Pisum sativum*	*Heterodera* sp.	+	+	+
Ladner—*Pisum sativum*	*Meloidogyne arenaria*	+	+	−

+ = Present.
− = Absent.

G. Steiner, Principal Nematologist, United States Department of Agriculture, suggested that the nematode was probably *Heterodera trifolii* (Goffart, 1932) Oostenbrink, 1949, the clover nematode, and that from Ladner, *Heterodera göttingiana*, the pea nematode. In correspondence, he indicated that host behaviour was entirely the basis for the separation of the two nematodes as species of *Heterodera*, and particularly referred to investigations of Goffart, who (1) found a nematode on red clover in Schleswig-Holstein and named it the "clover nematode", but discovered no morphological characters that would distinguish it from the pea nematode. On the other hand, through his later transfer experiments with the clover nematode and a study of the literature, Goffart (2) was able to report that the species of the *Leguminosae* attacked by the clover nematode were distinct from those attacked by the pea nematode, with the exception of *Vicia* which was a common host. The studies of Oostenbrink (3) on the clover and pea root nematodes have confirmed Goffart's statement that species of the legume family are attacked by two different strains of *Heterodera*. Oostenbrink also suggested that other strains must exist to account for the reports from the U.S.S.R. and Japan that alfalfa and soybean are hosts of a *Heterodera* sp. This suggestion is supported by the data in Table 2 which show that alfalfa and sweet clover can serve as hosts to both the Victoria and Ladner isolates.

Although, as collected at the nursery, the natural hosts of the Victoria isolate correspond closely with those of *H. trifolii*, studies by the authors have extended the range to include certain species of *Medicago* and *Lathyrus*, which are not normal hosts of *H. trifolii*, but which are listed as normal hosts of *H. göttingiana*. The Ladner isolate also has behaved in a manner that is typical of neither *H. göttingiana* nor of *H. trifolii*. If it is the

TABLE 2.—THE HOSTS OF *H. trifolii* AND *H. göttingiana* AS REPORTED BY GOFFART, AND BY OOSTENBRINK COMPARED WITH THE HOSTS OF THE ISOLATES FROM VICTORIA AND LADNER, BRITISH COLUMBIA

Hosts	*H. trifolii*		*H. göttingiana*		Victoria isolate	Ladner isolate
	Goffart	Oostenbrink	Goffart	Oostenbrink		
Lathyrus sp.	...	+	+	+	...	...
Lathyrus latifolius	...	...	...	...	+	...
Lathyrus odoratus	...	...	...	...	+	+
Lathyrus sylvestris	...	...	...	...	+	...
Medicago sp.	−	−	+	...	...	...
Medicago lupulina	...	−	...	?	+	...
Medicago sativa	...	−	...	−	+	+
Melilotus albus	...	−	...	−	+	+
Phaseolus sp.	+	...	...	...	...	...
Phaseolus vulgaris	...	+	...	−	+	+
Pisum sp.	−	−	+	+	?	+
Trifolium sp.	+	...	−	...	...	...
Trifolium dubium	...	...	...	...	+	...
Trifolium hydridum	...	...	...	...	+	...
Trifolium incarnatum	+	−	...	...	+	+
Trifolium pratense	+	+	...	−	+	+
Trifolium repens	+	+	...	...	+	...
Trifolium resupinatum	...	...	...	...	...	+
Vicia sp.	...	+	+	+	...	...
Vicia sativa	...	?	+	+	+	...
Vicia villosa	+	...	+	...	...	...

\+ = Positive. ? = Indefinite evidence (cysts only).
− = Negative. ... = No data.

former, it should not attack clover; if the latter, it should not attack peas. Except for the fact that transfers were effected with inoculum from pea roots, A. L. Taylor, of the Division of Nematology, United States Department of Agriculture, who is studying the identification of *Heterodera* spp. at Beltsville, Maryland, said that he would regard the results as evidence of mixed inoculum, but, because of the nature of the inoculum, it is suggested that the Ladner isolate might belong to a less specialized race capable of attacking the hosts of both *H. trifolii* and *H. göttingiana*. As a matter of fact, this view could also be advanced for the Victoria isolate, except for the fact that positive infection of peas by this isolate has yet to be established. Table 2 shows that the host lists of the two isolates are very similar. However, a loose cyst, which might have become detached in manipulation, was found among the roots of a pea plant grown in the nursery soil. Further work may show that the Victoria isolate will infect peas, for the number of nematodes per unit of nursery soil was small—much smaller than in the cultivated soil from Ladner.

Of special interest is the fact that, when clovers and peas were grown together, the Ladner isolate preferred clovers.

On the basis of the present evidence, the two isolates are probably the same species of *Heterodera*, for each has a strong preference for legumes, but is not specialized to particular species of them.

SUMMARY

The discovery of nematodes belonging to the genus *Heterodera* in a nursery near Victoria and also in a pea-field at Ladner in the Fraser Valley establishes the first records of the genus in British Columbia. Identification of the isolates was made by the Division of Nematology, U.S. Department of Agriculture, from a collection of naturally-infected hosts. The Victoria isolate was tentatively identified as *H. trifolii* and the Ladner isolate as *H. göttingiana*, and it was indicated that host specificity, as reported by Goffart (2) and Oostenbrink (3), was the basis for distinguishing the two isolates. However, transfer studies at Saanichton have established for each isolate a host range differing from that previously reported for the species with which it was identified. The Victoria isolate, identified as the clover nematode, infects certain species of *Medicago* and *Lathyrus*, normal hosts of the pea nematode. The other, identified as the pea nematode, infects certain species of *Trifolium* and *Phaseolus*, normal hosts of the clover nematode. The similarity of the host range of the two isolates suggests that they are the same species of *Heterodera*, characterized by a strong preference for legumes, but not specialized to particular species.

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